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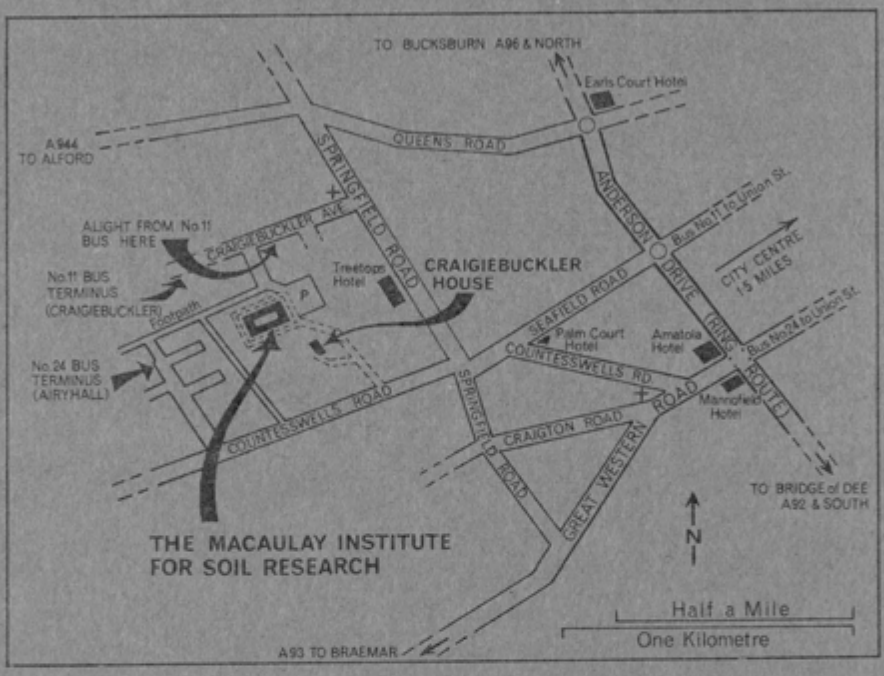

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The main part of this report covers the period from 1st October, 1975 to 30th September, 1976. The staff list is that current in November/December, 1976 and the Introduction is similarly updated. The report was published in May, 1977.

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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1975-76

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MISS R. MUNRO—appointed 3/11/75.
MRS I. M. SHAND.

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A M. ABBASS (Ministry of Agriculture and Natural Resources, Soil Survey Administration, Sudan).
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A. S. DE ENDREDY (FAO, Rome Italy). (Deceased February 1976).
*S. FORBES, Departments of Soil Fertility and Spectrochemistry, S.R.C. Student.
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*MISS R. M. WEST, Department of Microbiology, A.R.C. Student.

* Ph.D. Student.

CONTENTS

INTRODUCTION

The year reported on in this introduction to the Annual Report has been a busy and fruitful one for the Institute. Seventy-two scientific papers have been published and another sixty had been submitted for publication at 30th September 1976. Lectures have been delivered by members of staff in places as far afield as Japan and the U.S.A. and distinguished visitors from these and twenty-two other countries have come to hold discussions and sometimes to spend brief periods using special facilities at the Institute. During the year the Institute has been equipped with several highly sophisticated items of equipment such as an Electron Paramagnetic Resonance Spectrometer which will allow us to examine the forms in which agriculturally important transition metals are present in soils and plants and particularly how they are linked to soil organic matter. The acquisition of a Differential Scanning Calorimeter will allow us to make accurate enthalpy measurements on soils, minerals and soil organic matter, thus giving us an extremely fine tool for the characterization of soils and the provision of hitherto inaccessible information on their physical structure and behaviour. These two instruments are believed to be the first of their kind in the Agricultural Research Service. A rather unique tunable dye laser system is being assembled as a research project financed independently by grants from the Agricultural Research Council, the Science Research Council and the Royal Society. This powerful new laser will be used to stimulate intense power-regulated atomic fluorescence signals for trace analysis and will eventually be engaged in remote sensing of gaseous and other constitutents of agricultural atmospheres. These and lesser items such as new work on anodic/cathodic stripping voltammetry, differential pulse polarography, ion selective sensor electrodes, radio-frequency plasma emission spectrometry, atom-trapping atomic absorption spectrometry, will add considerably to the Institute's instrumental capabilities, e.g. spark source inorganic—and gas chromatography-linked—mass spectrometry, transmission and scanning electron microscopy, Mössbauer spectroscopy, infra-red and X-ray spectroscopy, radiochemical and thermoanalytical techniques, multichannel direct-reading emission spectrography, etc. There is little doubt that the Institute is fortunate in being one of the best equipped research institutes, not only in the Agricultural Research Service but in the U.K. as a whole. At the same time, the dependence of the Institute on high capital cost equipment does give some concern, particularly at the present time, in relation to the obsolescence factor which will be an increasingly urgent problem in the future and because of escalations in maintenance and service costs. In the latter instance one partial solution to this problem may be to expand the Institute's maintenance capabilities, particularly on the electronics side. The provision of more basic training in electronics for the staff concerned with such equipment may alleviate some of these problems in the future.

Research Programmes

Some aspects of the work of the Departments of the Institute are outlined in the following paragraphs under each discipline concerned. It should be stressed that these are in no way comprehensive and only a summary of *selected* items is given in each case. The individual reports for each Department should be read for a full account of the work done during the year.

PEDOLOGY

Work in the Chemistry and Mineralogy Section of the Department of Pedology is concerned with the processes by which soil is formed from rocks and minerals and the properties of the various components of the soil. The coarse (sand), medium (silt) and fine (clay) materials, formed by weathering, become recognisable as " soil " on incorporation of organic matter. Despite opinions to the contrary in some quarters, soil is much more than a framework holding plants upright for photosynthesis. Its minerals supply essential nutrients and it retains and modifies added fertilizer, thus controlling the rate of release of nutrients to plants and, on occasion, " fixing " nutrients in unavailable forms. The organic matter in the soil, as will be seen later, also has a pronounced effect on the growth of plants. The clay fraction with its large area of highly adsorptive surface has an influence on soil characteristics disproportionate to the amounts occurring and we are increasingly concerned with surface effects such as those associated with gel-organic complexes. However, weathering studies are currently yielding interesting information on the ability of coarser fractions to supply metallic ions, some, but not all, of which are beneficial to plants and the animals that subsist on them. Techniques employed in these and other studies include X-ray diffraction and fluorescence spectrometry, transmission and scanning electron microscopy, gas chromatography and mass spectrometry, differential thermal analysis, thermogravimetry, differential scanning calorimetry and specific surface-area determination as well as a whole range of chemical methods. These specialized techniques are also used in collaborative studies with other Departments of the Institute and with outside bodies as detailed in Section I of the Annual Report.

The Peat and Forest Soils Section is responsible for the surveying of peatland and, as will be seen, makes use of aerial and satellite photography for this purpose. Peat, which covers some 800,000 ha (2 million acres), or about 10%, of the land area of Scotland has in the past been widely used as a fuel and is presently an important raw material for industrial purposes as well as for the production of plant substrates, soil conditioners and other materials used in horticulture and agriculture. It is, therefore, one of our valuable natural resources and the qualitative and quantitative information provided by suitable classification and surveying techniques enables the Institute to advise Regional Development Boards and other bodies on the nature and development of deposits of interest. Special attention is being paid to the mineralization of nitrogen in peat, the stability of the physical structure of organic substrates and the factors affecting the incidence of

blossom-end-rot in tomatoes grown in peat composts. Peat is also an admirable medium for preserving pollen grains deposited from surrounding vegetation and identification of the pollen, thus preserved over the past 10,000 years or so, has enabled a useful picture to be built up of the climate and vegetation of Scotland in bygone days: recent observations have provided an insight into the history of the ancient Caledonian Forest. The information is being computer-stored in such a way that maps showing geographical and historical changes in the relative abundances of plant species can be readily obtained.

A study of water movement and drainage in soils using radioactive tracers is also in progress. This technique has been of value in afforested peatland and is currently being extended to mineral soils: concomitant studies concern aeration and plant-root development. The Department also contributes to the maintenance and improvement of the nation's timber resources through work, in collaboration with the Forestry Commission, on the nutrition of trees and nutrient cycling in the forest-soil system.

SPECTROCHEMISTRY

The Department of Spectrochemistry is concerned with studying the distribution of trace elements in soils and plants as it has always been, but increasingly now it is concerned with the forms in which these metals exist in the soil and in the plant, due to the availability of more sophisticated spectroscopic techniques such as electron paramagnetic resonance, Mössbauer and infra-red spectroscopy. It is also concerned with the inorganic and organic molecular components of soils chiefly through the deployment of infra-red absorption spectroscopy. Again, as in the past, the Department provides an analytical service for other Departments through the use of the above techniques, emission spectrography, atomic emission, atomic absorption and atomic fluorescence spectroscopy, molecular fluorimetry, etc.

During the past year Mössbauer spectroscopy has been used to characterize the forms of iron existing in the iron pans that are characteristic of many Scottish soil profiles. It has also been applied to the forms of iron existing in soil-forming minerals in podzolic soils, in plants and in iron humic-acid complexes. Electron paramagnetic resonance spectrometry has similarly shed light on the composition of soil humus, such as the binding of vanadium and the occurrence of copper-porphyrin complexes in the soil. Further work on molybdenum and copper is in hand with the newly acquired EPR spectrometer.

The total amounts of some 50 trace elements can now be determined simultaneously in soils in the range upwards from one part in ten million, as well as major elements semi-quantitatively, e.g. Ca, Fe, Mg, Mn, K, Ti, by recently developed techniques of spark-source mass spectrometry. Work is in progress to extend the technique to the analysis of plant-ash and chemical concentrates. The establishment of this multi-element technique creates an enormous knowledge of the elemental composition of soils and rocks which is likely to be of great significance in establishing soil-plant-animal relationships with respect to trace metal deficiency or toxicity in future work.

Soils treated with distillery wastes for a period of 50 years have been found to contain up to one hundred parts per million of extractable copper with their herbage levels up to the surprisingly high level of 40 ppm—possibly due in part to residual surface contamination. Similarly, soils treated with pig waste slurries for periods of up to 10 years have been found to contain up to 20 ppm of extractable copper. Work is continuing in conjunction with ADAS on the monitoring of extractable heavy metal content of soils treated with urban sewage sludges and of the corresponding herbage levels. Some of these local contaminations of the soil and the herbage grown on it must obviously give rise to a certain amount of apprehension that serious problems could arise for future generations should their incidence become widespread. These additions to the heavy metal status of the soil are virtually irreversible. Obviously central and local authorities must be appraised of the potential serious national problems involved and safeguard the future of the arable and grazing soils against any such general assault.

Not all trace problems are related to toxicity, however. Cobalt deficiency symptoms are common in animals on many Scottish farms due to low levels in the herbage which in turn arises from low levels of available cobalt in many northern soils. A repetition of earlier experiments has confirmed that the addition of about 2.24 kg ha^{-1} (2 lb/acre) of cobalt sulphate raises the cobalt content of herbage to a level sufficient for healthy stock. Selenium is another critical deficiency element for stock grazing on Scottish soils, especially those derived from the Old Red Sandstone and some granites. Investigations carried out during the past year have shown that for the limited number of soils examined so far the selenium levels range from less than one part in a hundred million to about one half part per million with a mean content of about one-fifth part per million. Work is now in progress, in conjunction with the Department of Soil Fertility, on sodium selenite and selenate treated soils and the plants grown on them to try to find a solution to these problems.

Infra-red absorption studies have shown during the past year how nutrient ions such as phosphate are bound to active hydroxide sites in the soil and similar processes have been shown to be responsible for the binding of many other ions including sulphate and nitrate, as well as soil humic and fulvic acids.

SOIL ORGANIC CHEMISTRY

The organic matter content of Scottish soils is relatively high and consequently the work of the Department of Soil Organic Chemistry is particularly important in understanding and promoting the fertility of the soil. Substantial parts of the soil's store of nitrogen, sulphur and phosphorus, for example, are present as organic compounds and many of the complex organic molecules in the soil are responsible for the binding and hence availability of essential and toxic trace metals. Some organic substances in the soil have pronounced physiological effects on plants, acting as growth regulators. As a whole the organic matter also modifies the physical properties of the soil such as its stability, ability to absorb heat, its water-holding capacity, degree of aeration and, of course, its drainage properties.

One of the most intriguing discoveries of the past year in the Department's work has been that synthetic maleic acid polymers can incorporate plant and microbial products such as phenols, amino acids, polypeptides, polysaccharides, etc., in their matrices to give materials that closely resemble soil humus in their properties and behaviour. The polymaleic acid itself has growth promoting properties similar to those of purified substances isolated from natural fulvic acid and water-extractable components of soil humus. The ability of this model compound to simulate the behaviour of humic components of the soil is of considerable importance in allowing further experiments to be carried out towards unravelling the structure of soil organic compounds and studying their effects on plant growth and nutrition.

Humic acid has been shown generally to promote the growth of wheat plants under conditions of iron deficiency or heavy metal toxicity by respectively mobilizing iron and immobilizing other heavy metals, and generally to improve root growth. However, this year, unexpectedly, a set of conditions has been found in which inhibition occurs in hydroponically grown plants over a narrow range of pH; fulvic acid behaves similarly at a slightly higher pH. It has also been shown that organic compounds extracted from soil by cold water can enhance the growth of wheat roots by as much as 10%. Work is now in progress to determine the identity of the species concerned in this behaviour. Another interesting facet of the work of the Department of Soil Organic Chemistry is shown by experiments on the effect of force fields on the growth of root systems. White light was found to inhibit root growth on a horizontal plane in species such as cress, but growth still occurred normally in a vertical plane. The inhibition on the horizontal plane was removed through centrifugation, probably by partial simulation of the earth's gravitational force field. Another interesting aspect arises from collaborative experiments with the Department of Plant Physiology *(q.v.)* in relation to the incidence of blossom-end-rot in tomatoes. The enzymic activity of invertase, phenolase and peroxidase is high in the afflicted areas, the phenolic level is increased threefold and the protein content is 50% higher relative to those in similar areas of fruit unaffected by the condition.

PLANT PHYSIOLOGY

The study of mineral nutrition and the mechanisms of nutrient transport within plants are the principal concerns of the Institute's Department of Plant Physiology. Thus, much attention is focussed on the translocation of species such as magnesium, calcium, sodium and potassium and on the physiological conditions that arise when imbalance is caused by a variety of factors such as may occur under normal growing conditions. The Department is also concerned with the effects of chelating agents within the plants under phytotoxic conditions and with the effects caused by external application of these agents. The Department relies for some of its analytical work on the Departments of Spectrochemistry and Pedology and collaborates closely with the Departments of Soil Organic Chemistry and Soil Fertility. Considerable use is made of techniques such as electrochemistry, gas

chromatography, light- and electron-microscopy, radiochemistry, etc., in studying various phenomena in plants.

During the current year work has continued on studying the induction of calcium deficiency in tomatoes which results in the incidence of blossom-end-rot (BER). It has again been confirmed by further experiments that BER can be induced at will by the application of nitrogen as ammonium fertilizer rather than as nitrate, even under conditions of calcium sufficiency and adequate watering regimes. This facility to allow BER to be induced has allowed studies to be made more easily on the associated higher enzyme levels (peroxidase, etc.) and chelant levels (phenols, chlorogenic acid, etc.), in conjunction with the Department of Soil Organic Chemistry. Cavity spot in carrots may be induced similarly. A theory has been evolved which may account for the incorrect watering explanation usually given for the incidence of BER in terms of the above observations, but further studies are required for verification, hopefully in the next Annual Report.

Further work continues on aluminium toxicity in species such as lucerne, and on the movement of inorganic ions within plants. It has been shown recently, for example, using the technique of compartmental flux analysis that, contrary to earlier beliefs, onset of net accumulation of sodium and chloride in aging beetroot storage tissue disks, results from changes in the fluxes at the *inner* cell membrane. At no time is entry of Cl^- to, or loss of Na^+ from, the cytoplasm significantly restricted.

MICROBIOLOGY

The microbial population of the soil has a vital role to play in several areas such as plant nutrition, plant growth and health, soil formation through decomposition of organic material and various effects on soil structure and texture, particularly in the all important microenvironment of the soil-plant interface where nutrition, etc., occurs. The Department of Microbiology concerns itself with these aspects in relation to actinomycetes, bacteria, fungi and protozoa, deploying its own expertise in areas as diverse as continuous flow culture of micro-organisms, axenic culture of plants, acetylene technique for measurement of nitrogenase activity, ciné and time-lapse photography, anaerobic bacterial culture techniques, ultra-violet/visible light microscopy, etc., as well as making extensive use of other instrumental facilities in the Institute such as electron microscopy, gas chromatography, the Institute computer, etc.

During the year 1975-76 the Department of Microbiology has been concerned *inter alia* with a study of the field populations of the fungus responsible for take-all disease in barley crops as a function of season and population of its antagonists. The incidence seems to have an interesting direct relationship to the ratio of ammonium to nitrate nitrogen applied, being most prominent at high values. Whilst this requires verification and more definite evaluation by further experiments, the implications for fertilizer application practices may be significant and some correlation may exist with similar findings for this ratio in another connection in the Department of Plant Physiology (*q.v.*). Continuing work on the sclerotia

of plant pathogens, particularly those responsible in recent years for rendering certain coastal areas in N.E. Scotland practically useless for growing peas—but which has caused little damage this year due to the very dry summer—has been devoted to ultrastructural studies of the composition of the fungal walls by electron microscopy and to the similar study of pea stem lesions caused by the fungus. The manner in which the fungus is able to enter potato leaves has also been established. This compilation of new information should be useful in deciding what measures could eventually be taken to combat this rather persistent hazard to crops such as those mentioned above.

Lastly, some mention should be made of recent work on a nitrogen fixing bacterium isolated from the roots of a selected strain of Canadian wheat. The extremely interesting observation has been made—again by electron microscopy—that in wheat grown in monoxenic culture the bacteria were found in intracellular spaces of the root cortical cells as well as in the mucigel. This presents the exciting possibility of a symbiotic nitrogen fixation capable of occurring for wheat under temperate conditions such as those prevailing in the United Kingdom. Much work requires to be done to confirm such a speculation, however, and the initial experiments are now being made collaboratively in this respect.

SOIL FERTILITY

The original responsibility placed upon the Macaulay Institute by its founder in 1930 was that it should research towards maintaining and improving the fertility of Scottish soils. As its name suggests, the Department of Soil Fertility is central to this purpose. The Department has a dual function in that it pursues its own aspects of fundamental and applied research, but is also responsible for the dissemination to the farming community, through the North of Scotland College of Agriculture Advisers, of the results of research carried out in the Institute. It is largely responsible for much of the Institute's consultative advice on soil problems to regional government bodies, the Department of Agriculture and Fisheries for Scotland, etc., and collaborates extensively with the other Departments in much of the Institute's work programme. As would be expected for such a wide ranging responsibility, the Department's staff have expertise in disciplines as different as agronomy, botany, crop physiology, physics and most branches of chemistry.

During the year 1975-76 the Department has, as usual, paid attention to several aspects of crop responses to fertilizers. For example, considerable interest arises from the response of some of the newer varieties of barley, which have a higher than usual nitrogen requirement, in relation to some of the newer, e.g. liquid, formulations of fertilizer where chemical composition differs from the standard granular materials, particularly in containing urea. Some useful conclusions were drawn this year, *q.v.*, but in view of the unusual weather conditions during part of the trials these can only be regarded as tentative at present. Another interesting feature of this aspect of the Department's work relates to the time of application of nitrogen fertilizers to barley. Despite the higher nitrogen requirement of some of the new

varieties and the formulation of fertilizers to contain more nitrate nitrogen, which is more easily lost by leaching, no significant difference in response was found between application at seed sowing or 6-8 weeks later, even though 90 mm of rain fell in the meantime. Work was started during the year on the phosphate response of barley in relation to minimum cultivation techniques under Scottish conditions. No obvious difference was found in this respect between normal ploughing, chisel ploughing and no ploughing, but it was noticeable that couch grass was less prominent in the traditionally ploughed area. Another series of experiments examined the effects of placement and broadcasting techniques for nitrogen and for NPK fertilizers on Swedish turnips. Little difference was observed with straight ammonium nitrate. With NPK fertilizers, however, the expected beneficial effect of placement (5 cm below the seed) in improving the effectiveness of phosphate was evident, especially on soils of high phosphate sorption capacity, e.g. the Insch series, relative to those of moderate capacity, e.g. Countesswells series. The indications are that modern fertilizer formulations based on ammonium phosphate and nitrate may be more safely used by placement than older ones based on ammonium sulphate and superphosphate.

One of the most intriguing results of recent work is the finding that, contrary to widely held views, barley yields are more closely related to growth *before* rather than after ear emergence. This suggests that sink capacity, i.e. the number of grains per unit area, is more important than photosynthetic yield after ear emergence and implies that the carbohydrate supply by mobilization from the straw is usually sufficient to fill the ears, despite deficiencies in photosynthesis that often occur during the ear filling period. During the second half of ear filling as much as 70% of the increase in the dry weight of the grain may be supplied in this way. These conclusions indicate that proper nutrition of the plant at the stage before ear emergence may be a more critical factor than has hitherto been thought. Some re-examination of the importance of straw in relation to yield may also be beneficial for future consideration in the evolution of new strains of barley.

Although Scottish soils are not normally deficient in sulphur, work on sulphur levels in different soils and on the sulphur contents and sulphur: nitrogen ratios of crops is being undertaken. Approximately 50% of the total soil sulphur is carbon-bonded and up to 30% of the latter is present as sulphur-containing amino acids. The magnesium and potassium status of most Scottish soils is also generally satisfactory, in comparison to the widespread deficiencies of lime and phosphate. Nevertheless, in view of the increasing intensity of cropping at the present time, the Department of Soil Fertility is screening different soil types for potassium and magnesium supply status. Five soil series are currently being examined for their differing abilities to mobilize ion-exchangeable forms of potassium and magnesium following depletion by continuous cropping with ryegrass.

Advisory work on Scottish soils, which are generally acidic, has shown that during the past ten years the lime status has remained fairly constant. About 850,000 tonnes of $CaCO_3$ would require to be applied annually to maintain the 1,250,000 ha of arable land at pH 6·0 and the 414,000 ha of

permanent grass at pH 5·6. There is, however, an immediate need for about 5,700,000 tonnes of $CaCO_3$ to correct outstanding deficiencies. There are also 5,000,000 ha of rough grazing, most of which could be improved considerably by liming. Productivity could, of course, be improved in an alternative fashion on the Scottish scene by the evolution of species capable of optimal yields at lower pH values. This could reduce annual lime maintenance costs by as much as 50%.

On the more fundamental side of its programme, the Department is engaged on sorption/desorption studies of plant nutrient anions, especially phosphate, in various soils, and is making use of modern techniques, such as microcalorimetry. Soils are also being characterized with regard to their physical properties, such as bulk density, pore-space relationships, moisture release characteristics and hydraulic conductivity, with a view to assessing effects on crop yields, etc. Electroanalytical procedures have been developed for measuring ammonium ions in soil extracts, using an ammonium responsive electrode, and for estimating nitrate directly in moist soil with a nitrate selective electrode. Direct ion-selective electrode procedures have also been standardized for potassium and calcium + magnesium in soil extracts, and potentiometric and voltammetric techniques are being investigated for phosphate. Techniques of differential pulse polarography and cathodic stripping voltammetry are also being examined for various trace elements, including selenium. As a deficiency element in many Scottish soils, selenium causes enzootic muscular dystrophy in livestock and there is particular need for a more sensitive technique capable of being used for more extensive diagnostic deficiency studies.

Lastly, mention should be made of the radioactivity unit which supplies isotopically labelled experimental facilities for other Departments such as Plant Physiology, Soil Organic Chemistry, Pedology and Microbiology, and thus provides an invaluable service throughout the Institute's work programme.

STATISTICS

Few natural materials are more complex than the various types of soil on which the Institute bases its work and few conditions can be more variable than those which perturb experiments on crop growth and yield. Consequently the expertise of the Department of Statistics is fundamental to ensuring sound statistical design of experiments and ensuring that valid conclusions may be drawn from the complex accumulation of data. The work of the Department is consequently so interwoven with the fabric of research in most other Departments that it is difficult to isolate specific items solely relevant to the Department itself. Its influence is disseminated across the entire spectrum of the Institute's programmes whether one looks at largely technique-oriented Departments such as Pedology and Spectrochemistry or more mission-oriented ones such as Soil Fertility and Soil Survey. However, special mention may be made of the investigation of experimental design systems, of new methods of data analysis, programming and operation of the Institute's computer system, simulation of growth processes, model building for various agricultural problems, e.g. drainage and nutrient re-

cycling in different ecosystems. The Department is also the prime mover in establishing a soil data bank which will eventually allow much more efficient correlation of data on soil series, trace metal status, pedological data, fertility data, etc., than is possible with the limited punched card index systems, etc., presently used in the different Departments. This is a long-term project which will have to be continually updated, but it will unquestionably have a profound effect on the work of other Departments and contribute greatly to the effectiveness of the Institute's research and its ability to provide a service to the community.

SOIL SURVEY

The Deparment of Soil Survey carries the responsibility for inventory, description and mapping of the soils of the land area of Scotland. Since 1947, it has completed this task for over 50% of the land surface, including more than 90% of the arable soils and more recently has started systematically to produce land use capability assessments and maps which have been of very considerable use to regional planners in particular and serve directly to safeguard against loss of the nation's most precious natural resource—its good arable soils. Climatic and Vegetation maps have also been produced. The Department acts as a consultant on special issues to the Department of Agriculture and Fisheries for Scotland, to Regional Councils, to National Corporations, etc., in connection with the siting of gas-pipe lines, highway routes, open-cast mining, oil installations, housing developments, etc. The achievements of the Department since 1947 are summarized in the introductory paragraphs of its report.

During the current year, the Department has surveyed another 1445 km^2 (560 sq. miles) of soils, with simultaneous assessment of their land use capability characteristics and has described two hundred and eight soil profiles and sampled them for analysis.

Some rather interesting areas of salt-affected soils in the Orkney Islands have been noted that sometimes have organic surface horizons, but exhibit a curious strong coarse columnar structure. In addition to systematic soil survey, all site investigations for the new A9 trunk road have been completed during the year and work is well on the way to establishing a chronosequence for podzolisation in the Central Highlands. Special surveys have been undertaken along the A9 route, as mentioned above, for the Scottish Development Department; of Kyllachy, Corrybrough and Rothiemurchus estates in collaboration with the North of Scotland College; Lephinmore farm for the Hill Farming Research Organisation; Oatridge farm for the Oatridge Agricultural College; the environs of Lochgilphead for the Argyll District Planning Authority and the track of the gas pipeline between Roberton (Lanark) and Canonbie (Dumfries) for the British Gas Corporation.

Revised tables of vegetation of the Lowland and Southern Upland Regions have been prepared and a monograph has been published on the plant communities of the same areas. Considerable work is going on in the production of phyto-sociological records, particularly in the Orkney Islands. Assistance has been given to the Soil Survey of England and Wales in establishing the

boundaries of the subzones of oceanicity in England and Wales. Micromorphological studies have been focussed largely on clay movements during soil profile development. As in the past, close liaison has been maintained with many other organizations working over the same terrain, e.g. the Forestry Commission, the Nature Conservancy Council, the Institute of Terrestrial Ecology, the Highlands and Islands Development Board, the Countryside Commission, the Hill Farming Research Organisation, etc.

At the present time considerable thought is being given to a sub-division of the Class 3 land of the Macaulay Land Use Capability System now that the latter has been adopted by the DAFS for all future classification work in Scotland and to the scale, detail and nature of required information for the hill land survey with which the Department will be increasingly concerned in the future. The present time is, therefore, one of orientation in which changes are envisaged in survey and mapping techniques over the next few years. The response that is now being received to the land use capability mapping programme is very encouraging and may demand intensification of effort in this area.

EVENTS AND PEOPLE

First T. B. Macaulay Lecture

As the Institute comes close to its 50th anniversary it seemed appropriate to initiate an annual T. B. Macaulay Lecture for the benefit of the staff and to act as a focal point for the lectures and colloquia which had been reintroduced following an interval during which Craigiebuckler House was refurbished. The Council of Management gave this proposal its wholehearted support and undertook to finance the lecture annually from funds at its disposal. The lecture is to be given by a distinguished scientist who has made noteworthy contributions to soil science or in one of the disciplines as represented by the Departments of the Institute or related areas. Accordingly on 25th November, 1976, the first T. B. Macaulay lecture was delivered by Sir William Henderson, F.R.C.V.S., F.R.S., Secretary to the Agricultural Research Council, who chose as his title " Science Policy for Agriculture ". Sir William talked to a packed audience of *ca.* 200 Institute staff, members of the Council of Management, visitors from other Institutes and the University, in the Marine Suite of the Amatola Hotel. Professor T. C. Phemister, Chairman of the Council of Management, took the chair and the vote of thanks and presentation of the memorial scroll was undertaken by the Deputy Director of the Institute, Dr E. G. Williams. The photograph shows the scroll being examined by Dr Williams, Professor Phemister and Sir William. The citation on the scroll, which was specially produced by the Institute cartographers reads:

> " Presented to Sir William Henderson, Secretary of The Agricultural Research Council, London, England, in recognition of his outstanding services to agricultural science and in commemoration of the occasion of the First T. B. Macaulay Lecture delivered at The Macaulay Institute for Soil Research in Aberdeen, Scotland, on 25th November, 1976."

Left to right, Dr E. G. Williams (Deputy Director), Prof. T. C. Phemister (Chairman) and Sir William Henderson examine the scroll presented to Sir William following delivery of the First T. B. Macaulay Lecture.

Sir William's lecture is printed in full as the appendix to this report. It is a pleasure to take this occasion to express our gratitude to him for giving us his time and attention and for setting the Macaulay Lecture Series off to such a splendid start. It is hoped to hold subsequent T. B. Macaulay lectures at approximately the same time of year, *i.e.* just before or after the November meeting of the Council of Management.

Meetings and Lectures

The executive of the Analytical Division of The International Union of Pure and Applied Chemistry (IUPAC) met in Craigiebuckler House, September 1st-3rd, and two members of the group gave short talks to the staff. Professor N. Tanaka, Tohoku University, Sendai, Japan, spoke on electro-analytical chemistry and Dr J. C. White, Union Carbide, Oak Ridge National Laboratory, Tennessee, spoke on energy options in the U.S.A. During the year other external speakers in the colloquia series were Dr J. V. Lagerwerff, U.S Department of Agriculture, Beltsville, Maryland, on Heavy Metals in the Agricultural Environment; Professor S. Tsuge, University of Nagoya, Japan, on Pyrolysis Gas Chromatography; and Dr H. Egan, Government Chemist, London, on The Work of the Government Chemist's Laboratory. Meetings of other scientific bodies in the Institute buildings included a joint one between the Aberdeen Biochemical Association and

the Aberdeen Section of The Chemical Society, 6th May; the British Cartographic Society's Annual Technical Symposium, 17th September; and The Electron Microscope Users Group, 2nd November.

Broadcasts

Short broadcasts on Institute matters were made at various times during the year by Dr R. C. Mackenzie (Pedology), Dr R. Glentworth (Soil Survey), Mr R. A. Robertson (Pedology) and the Director. Mr Robertson, head of the Peat and Forest Soils Section of the Department of Pedology, appeared twice on television and there were one television and two radio interviews given by Sir William Henderson following his delivery of the T. B. Macaulay Lecture.

Honours and Appointments

During the year, Professor J. I. G. Cadogan, member of the Council of Management, was elected to Fellowship of The Royal Society. The Director was presented with the 1975 Chemical Society Award for Chemical Analysis and Instrumentation, a bronze medal and cheque for £100, and with the INTERAN '76 medal at the International Conference on the Analysis of Geological Materials in Prague, Czechoslovakia. Dr B. L. Sharp (Spectrochemistry) became the first recipient of the Rank-Hilger Prize for Atomic Spectroscopy awarded by the Atomic Spectroscopy Group of the Analytical Division of The Chemical Society to analytical spectroscopists under the age of 30 for his notable contributions to research in atomic fluorescence spectroscopy.

The Director was re-appointed Chairman of the Analytical Sub-committee of the Royal Society's British National Committee for Chemistry for a further period of three years and, ex-officio, a member of the BNCC. He was also appointed to membership of the ARC Instrumentation Group and succeeded Dr R. L. Mitchell as a member of the Advisory Committee on Forest Research of the Forestry Commission. Dr R. C. Mackenzie, Head of the Department of Pedology was elected to the Nomenclature Committee of L'Association Internationale pour l'Etude des Argiles, the Organizing and Scientific Programme Committees of the International Clay Conference 1978 and to the Committee of the Thermal Methods Group of the Analytical Division of The Chemical Society. Mr R. A. Robertson was re-elected Vice-President of the International Peat Society at its meeting in Poznan, Poland. Mr B. D. Mitchell and Dr M. J. Wilson have both been appointed to the Scientific Programme Committee of the International Clay Conference 1978. Mr J. M. Bracewell became a member of the ARC Panel on Mass Spectrometry; Dr H. G. Miller was appointed to the Committee of the Sylvicultural Group of The Royal Scottish Forestry Society and Dr W. J. McHardy to the Committee of the Aberdeen Electron Microscope Users' Group.

Dr R. O. Scott, Head of the Department of Spectrochemistry, was appointed by The Royal Society as the British National Representative on the V4 Spectrochemistry Commission of IUPAC and to membership of the

Analytical Sub-committee of the BNCC. Dr V. C. Farmer became Vice-chairman of the Scientific Programme Sub-committee of the International Clay Conference 1978, and Associate Editor of the Proceedings of the International Clay Conference. Dr A. M. Ure became Chairman of the Scottish Region of the Analytical Division of The Chemical Society and ex-officio a member of the C.S. Analytical Division Council. Dr M. L. Berrow was appointed Chairman of the Inorganic Constituents Panel of the DOE Standing Committee of Analysts' Working Group on Sludge and Related Solids.

Dr J. W. S. Reith, Department of Soil Fertility, was appointed to the Scottish Farm Waste Committee of the Scottish Agricultural Development Council and to the DAFS Working Group on the Disposal of Sewage Sludge to Agricultural Land. He and Dr P. W. Dyson also became members of the Study Group of the DAFS Working Party on Land Use Capability Classification. Mr R. H. E. Inkson, Head of the Department of Statistics was re-elected to the Committee of the Highlands Group of The Royal Statistical Society following the expiry of his period as Chairman. Mr R. Grant, Head of the Department of Soil Survey, was appointed to the DAFS Working Party on Land Use Capability Classification for the Low Ground of Scotland and became with Mr J. S. Bibby and the two staff of the Soil Fertility Department mentioned above, a member of the Study Group. Mr Grant and Mr Bibby also became members of the DAFS Working Party on Land Classification for the Hill areas of Scotland. Mr Bibby was appointed as Chairman of its Technical Group with Mr Grant and Mr J. S. Robertson as members of the Sub-committee. Mr Bibby has also been elected a member of the Council of the British Soil Science Society. Mr J. M. Ragg was appointed a member of the Scottish Development Department's Working Party on Rural Land Use Information Systems, the MAFF-ARC-ADAS Soil Survey Working Group on Suitability for Direct Drilling and represents both the Scottish and English Soil Surveys on the Ordnance Survey Advisory Committee on Survey and Mapping.

Lectures and Visits Overseas by Institute Staff

During the year the Director accepted an invitation from the organizers of the Pittsburgh Conference on Applied Spectroscopy to deliver the plenary lecture on Atomic Spectroscopy at their Bicentennial Symposium in Cleveland; the visit was financed by the organizing committee. He also accepted an invitation to act as Visiting Professor to various Japanese Universities in April for approximately four weeks. This visit was sponsored by the Japan Society for the Promotion of Science.

Profitable visits were made by several members of staff to various research establishments and scientific conferences abroad with the aid of funds made available by the DAFS. Dr G. Anderson (Soil Organic Chemistry) attended a Symposium on the Role of Phosphorus in Agriculture at Muscle Shoals, Alabama, U.S.A., in June. Dr F. J. Darbyshire (Microbiology) attended the VIth International Colloquium of the International Soil Science Society, Soil Zoology Committee in Uppsala, Sweden, in June. Dr J. W. S. Reith attended a conference on " Very Long-term Fertilizer

Experiments and their Results" at the Centre de Grignon, Thiverval-Grignon, France, in July, and thereafter visited the Agricultural Research Centre at Versailles. Dr A. E. S. Macklon (Plant Physiology) attended the International Workshop on Membrane Transport in Plants at Paris-Rouen, in July. Dr D. Vaughan (Soil Organic Chemistry) attended the 10th International Congress of Biochemistry in Hamburg in July. Professor T. S. West attended the INTERAN '76 Conference in Prague, Czechoslovakia, in August. Dr A. M. Ure (Spectrochemistry) attended the 7th International Mass Spectrometry Conference in Florence, Italy, in August. Mr J. M. Bracewell (Pedology) attended the Third International Symposium on Analytical Pyrolysis in Amsterdam, The Netherlands, in September. Dr B. A. Goodman (Spectrochemistry) attended the Third International Conference on Application of the Mössbauer Effect, in Corfu, Greece, in September. Mr R. A. Robertson (Pedology) attended the Fifth International Peat Congress and meetings of the Presidium and Council of the International Peat Society, in Poznan, Poland, in September. Mr Robertson also attended a meeting of the Executive Committee of the International Peat Society in Helsinki, in June. Mr A. H. Knight attended the VIIth Annual Meeting of the European Society for Nuclear Methods in Agriculture in Warsaw, in September.

Postgraduate Research Students

During the year 1975-76 there has been a welcome influx of postgraduate research students in several Departments. Mr S. Cooke (Soil Fertility) is working on the determination of acidic species such as nitrogen oxides and sulphur dioxide at normal atmospheric levels by a new technique of piezoelectric response under support of the Ministry of Defence. Mr S. Forbes (Soil Fertility/Spectrochemistry) is supported by the Science Research Council and is studying linked electrochemical/spectroscopic techniques for the determination of selenium at the low crop/soil levels likely to cause muscular dystrophy. Miss J. Khaligie (Spectrochemistry) is engaged on research to trap or condense atomic species in flames with a view to their subsequent release into the flame and measurement by atomic absorption spectroscopy. Mr D. A. P. McKay (Statistics) supported by the Agricultural Research Council, is researching into the setting up of a computer-based information system for storage, retrieval, analysis and presentation of soil data. Mr P. J. Monks (Soil Fertility) supported by the Ministry of Defence is, like Mr Cooke, engaged on the establishment of a piezoelectric crystal monitor system for following atmospheric levels of basic species such as ammonia and amines. Mr A. R. Morrisson (Spectrochemistry) supported by the Agricultural Research Council, is assisting with the construction and utilization of a tunable dye laser system for the excitation of atomic fluorescence spectra and eventually, it is hoped, for the remote sensing of gaseous and other species in agricultural atmospheres. Lastly, Miss R. M. West (Microbiology), supported by the Agricultural Research Council, is researching into the effects of soil bacteria, fungi and protozoa in the rhizosphere on the decomposition of roots of crop plants with a possible extension to studies of the effects of common agricultural practices (fungicides,

herbicides, N-fertilizers) on microbial populations in the rhizosphere and subsequent root decomposition.

Overseas Research Workers

In addition to these seven postgraduate research students, it will be seen from the staff list that there was a total of fourteen other long-stay visiting research workers in the Institute this year from countries as far apart as Canada, Japan, Turkey and the Sudan. The Institute benefits considerably from their cross-section of experience and expertise; their presence is most welcome.

Retirement of Senior Staff

During the year the Institute has lost the services of two of its most experienced Heads of Department; Dr R. Glentworth of Soil Survey who had been a member of staff since 1939, and Head since 1946, and Dr D. M. Webley of Microbiology who had become the founding Head of his Department in 1947. We are greatly indebted to both men for having served so long and so well. Both have established very fine reputations for their Departments and have built in behind them very competent and effective research teams. It is a fitting comment on their achievements that their successors should have been drawn in both cases from their own Departmental teams against keen competition from within and without the Institute. Tributes to both men have appeared in Profile (*q.v.*) Dr J. F. Darbyshire, a member of staff since 1964, succeeds Dr Webley as Head of the Department of Microbiology, and Mr R. Grant, a member of staff since 1950, succeeds Dr Glentworth as Head of the Department of Soil Survey and Soil Survey of Scotland.

Deaths

On December 10th the Institute suffered the loss of Dr T. B. Miller, a member of the Council of Management. His untimely death came as a great shock that was felt keenly by many members of staff who knew him well. We also record with regret the death of Professor Sir Stephen Watson who had previously served on the Council for twenty-four years, three of them as Convener of the Finance Committee. Dr A. S. de Endredy, a long standing " unofficial " member of the staff of the Department of Pedology, died on February 6th, 1976. His contribution to the Institute was highly appreciated and is referred to in the Department's report and in more detail by Dr Mackenzie in the March 1976 issue of Profile and Bulletin No. 49 of the International Society of Soil Science.

Institute Events

A new Institue magazine, " Profile," was launched in February and has appeared regularly every month subsequently. The Editor is Miss E. M. Watson, the Institute's Information Officer, with representatives of each Department, Technical Services and Administration, acting as the Editorial Board. It serves as a vehicle for official announcements, news and views,

club and society information, correspondence column and informative articles on a surprisingly broad spectrum of topics. We hope that it will be possible to continue with this very successful venture in the coming year. It is a pleasure to record the Institute's thanks to all concerned in the production and presentation of Profile. Significantly we have already had a request to reproduce an article in another journal. Profile is distributed to all members of staff and former staff and to Members of Council who wish to receive it.

" Health and Safety at Work " is another publication issued during the year. This Code of Practice, which arose out of the deliberations of The Safety Committee and particularly the untiring efforts of Mr A. H. Knight, the Institute's Safety Officer, gives a fairly full account of measures for ensuring the safety of the staff at work in the Institute, with appendices, etc., giving more specific information on emergencies, hazards, precautions, simple procedural rules, etc. This first edition of HASAW, which has been issued to all members of staff and visiting research workers in a cyclostyled format, will be revised subsequently in the light of experience and put out eventually as a printed pamphlet. A third publication " Horizon " to act as an introductory pamphlet for visitors to the Institute and for new members of staff is now nearly completed and should become available in 1977.

With the consent of the Council of Management, a Consultative Committee was formed early in the year with the express purpose of promoting the greatest measure of co-operation between the official and staff sides on matters of mutual concern and with a view to maintaining and improving the harmonious working of the Institute and the well-being of the staff.

The Committee is comprised of the Director, Deputy Director, Secretary and one Head of Department, constituting the " management " component, and the Chairman, Vice-Chairman, Secretary and one ordinary member of the Institute's Institution of Professional Civil Servants Committee, constituting the " staff " side. The Civil Service Union also has access to the Committee and is consulted by the Director concerning items of Agenda before meetings. Two meetings (20th February and 8th November) were held during the year. These were very constructive and have proved extremely useful and worthwhile. It is anticipated that this new channel of communication should contribute considerably to the harmonious working of the Institute and the well-being of the staff.

An experimental period of flexible working hours was introduced in May following the meeting of the Consultative Committee. The scheme operates on a trust system and the initial experiment has worked very well without staff having to " clock in and out " at least four times every day. During the forthcoming year it is proposed that the bandwidth of the working day will be extended to facilitate travel to and from the Institute, well outside the conventional 9 to 5 working day of the city.

The Council of Management met twice, on 26th May and 26th November. On both occasions the staff were very pleased to welcome the members who looked round the various Departments of the Institute and to have the opportunity to discuss their work with them. As mentioned previously, several members of Council also attended the Macaulay Lecture and met

members of staff informally during the process. It is hoped that this contact may be maintained and augmented during 1977.

T. S. WEST

The departmental responsibilities for individual research projects are discussed in the Report as follows:

100	Pedology	500	Microbiology
200	Spectrochemistry	600	Soil Fertility
300	Soil Organic Chemistry	700	Statistics
400	Plant Physiology	800	Soil Survey

In addition to the research projects, a number of service projects are also listed. When these are non-departmental, provided by Technical Services or Administration, they bear a 900 series identification, while for inter-departmental services for which one department is responsible, the appropriate series number of that department is prefixed by 5. A list of service projects follows that of the research projects.

PROGRAMME OF WORK

RESEARCH PACKAGES AND ASSOCIATED PROJECTS

PACKAGE 1: The study of the development and composition of mineral soils and their size fractions.

Objective: To elucidate the factors that control the composition and contribute to the physical and chemical properties of mineral soils. So to provide information that could help to explain differences in soil structure and soil behaviour.

(a) Characterization of Minerals and Major Constituents

Projects

101 Scottish soil types: chemical and physical characterization in relation to development.

103 Soil mineralogy: relationship with soil type and soil properties.

104 Minerals: alteration during weathering and soil development.

107 Mineral and organic soils: development of chemical and instrumental methods of examination.

108 Mineral and organic soils: characterization by products of thermal decomposition.

109 Mineral and biological materials: structure and composition by electronoptical and electron probe methods.

(b) Trace Element Characterization

201 Distribution and location of trace elements in soils: effect of soil parent material and drainage conditions.

204 Geochemical distribution and pedological behaviour of trace elements.

205 Development of techniques for the determination of trace elements: direct reading methods and computer processing.

206 Development of flame emission and atomic absorption methods: instrumentation and techniques for trace and major elements.

703 Development of computer techniques and programs.

PACKAGE 2: The study of the nature and surface properties of soil clay minerals and mineral-organic matter complexes.

Objective: To investigate the factors involved in the surface and colloidal reactions of soil minerals, particularly of the clay minerals and complexes that participate in the mobilization or binding of plant nutrients in the soil.

Projects

105 Soil colloids: nature, origin and behaviour of inorganic, organic and organomineral complexes.

106 Surface characteristics of soil particles.

207 Characterization of soil minerals and study of their surface properties and weathering by infrared methods.

304 Chemistry of soil-organic-matter: mineral complexes.

PACKAGE 3: The survey and classification of the mineral soils of Scotland.

Objective: To map and classify soils systematically according to their parent materials, pedological drainage and other field characteristics: to produce land use capability maps. The systematic survey identifies soil types and enables other departments to investigate the cause of differences in their fertility and other soil properties.

Projects

801 The systematic survey of Scottish soils.

804 Studies of soil structure and genesis.

PACKAGE 4: The study of the nature and properties of soil organic matter.

Objective: To determine the nature of the organic materials in soils at different stages of decomposition under different pedological conditions and to ascertain its contribution to the physical structure and chemical behaviour of soils and its effect on the growing plant.

Projects

208 Characterization of soil organic matter by infrared and ultraviolet methods.

303 Nitrogenous constituents of soils, peat and leaf litter: relationships with co-occurring macromolecules.

305 The synthesis and degradation of polysaccharides and related constituents of soil organic matter.

307 Characterization of soil humic substances by means of their paramagnetic properties.

309 The effect of organic constituents of soil on the growth and nutrition of plants, with particular reference to processes involving the root.

311 The effects of organic constituents of soil on biochemical processes in plants.

PACKAGE 5: The investigation of the role of soil microorganisms in soils and in soil-plant relationships.

Objective: To assess the effects of soil microorganisms in the breakdown of organic material in soil and to study the interactions between soil microorganisms and plants in order to ascertain the nature of their contribution to crop growth yield.

Projects

301 Chemical and biochemical investigations of organic material of microbial origin.

501 Incidence and characteristics of lytic microorganisms in the root region of cereals.

502 Production of cell material and by-products of soil microorganisms.

503 Microorganisms involved in the decomposition of peat and its components.

504 Interrelationships of soil protozoa and bacteria inoculated on axenic (microorganism free) plant roots.

505 Interrelationships of soil protozoa with other soil microorganisms.

506 Microbial degradation of soil organic matter as influenced by clay minerals.

507 Ultrastructure and chemical composition of soil fungi, including plant pathogens.

508 Soil-borne fungal parasites.

509 Soil protozoa in the metabolism of soil organic matter.

510 Investigation of soil protozoan populations.

511 Physiology of actinomycetes in soils.

PACKAGE 6: The study of the nature and distribution of organic soils and peat in Scotland.

Objective: To survey and classify the peat deposits and organic soils in Scotland and to study their utilization and potential fertility for agricultural, horticultural and forestry purposes.

Projects

110 Organic soils: moisture retention and root development.

111 Organic soils: site capability and amelioration.

112 Scottish peat deposits: survey, classification and characterization.

113 Pollen and plant-fossil analyses: post-glacial vegetational and climatic changes.

114 The use of peat and peat products in agriculture and horticulture.

116 Nitrogen mineralization: factors controlling release of nitrogen immobilized in peat and humus.

PACKAGE 7: Investigations on the fertility of soils and the yield of agricultural crops.

Objective: To investigate factors controlling, and to study means of improving, the fertility of agricultural soils by related field, pot and laboratory studies on soil nutrient status, fertilizer usage and crop yield.

(a) Soil-Nutrient Relationships

Projects

203 Forms of occurrence of trace elements in soils and the mechanism of their movement towards the plant root.

317 The nature and properties of organically bound phosphate in soils.

601 Inorganic soil phosphorus and sulphur: evaluation of available forms and effects of fertilizers.

602 Organic phosphorus and sulphur in relation to soil type and nutrient supply.

603 Available nitrogen in soils.

604 Soil acidity: aluminium solubility and cation exchange equilibria in different soil types.

605 Anion sorption: kinetics and equilibria of phosphate reactions in relation to soil composition.

611 Soil potassium and magnesium: distribution, solubility and availability in different soil series.

612 Soil physical conditions and crop growth.

(b) Soil-Plant Relationships

607 Growth, development, nutrient accumulation and yield of field crops: effects of environment and management.

608 Field responses to nutrients: soil type effects and prediction of fertilizer requirements.

609 Trace element status of soils and crops: effects of soil type: diagnosis of deficiencies and excesses.

610 Assessment of lime and nutrient status of soils.

701 Design and analysis of experiments including crop response functions and the fitting of response surfaces.

702 Relationship of crop yield and composition to soil properties, and the numerical classification of soils.

PACKAGE 8: The study of factors affecting crop composition.

Objective: To investigate the effects of soil conditions on crop composition and to study plant-physiological aspects of soil-plant relationships. The content of the plant and its individual parts may have particular reference to soil-plant-animal problems related to both major and trace nutrients.

Projects

202 Trace element uptake by plants: distribution in different species and plant parts.

401 Iron and copper metabolism of plants.

402 Uptake and physiological effects of chelated trace elements on plants.

407 Salt absorption: physical and metabolic aspects.

408 Nitrate reductase and molybdenum-copper interactions in plants.

606 Inorganic and organic constituents in crops: forms, patterns and balance in relation to age and yield.

613 Development of radioactive techniques.

PACKAGE 9: The study of the fertility of forest soils and other non-agricultural soils and their natural vegetation.

Objective: To study the nutrition of conifers and other non-agricultural crops on forest soils, peats and other soils of limited capability. To study the natural vegetation in relation to soil type and to consider means of improving the utilization of marginal land.

Projects

115 Conifer nutrition: nutrient cycling, tree growth and influence of fertilizers.

117 Nutrient deficiencies in conifers: diagnosis and amelioration.

802 Plant communities and their relation to genetic soil types.

A research grant from the Forestry Commission contributes towards the cost of the forest soil projects.

SERVICE PROJECTS

Non-Departmental

Projects

901 Provision of Instrument Workshop facilities.

902 Provision of Photographic facilities.

903 Provision of specialized materials and equipment.

Departmental

Projects

5107 Mineral and organic soils: application of chemical and instrumental methods of examination.

5205 Application of techniques for the determination of trace elements: direct reading methods and computer processing.

5206 Application of flame emission and atomic absorption methods for trace and major elements.

5313 Provision of analytical facilities employing special equipment.

5314 Supervision and maintenance of general glasshouse facilities.

5613 Provision of radioactive facilities.

5701 Production of designs for experiments and statistical analysis of data.

5703 Data preparation and computer processing.

1. PEDOLOGY

DR R. C. MACKENZIE

The work of the department continues along the lines previously established with the aim of obtaining a better understanding of the origin and properties of the complex soil system by the application of scientific techniques of investigation.

Samples from profiles characterized by Soil Survey in the field and examined in the laboratory by chemical, physical and mineralogical techniques provide a valuable source of material for research work in all departments of the Institute. For this reason all profile samples have been retained since commencement of the Soil Survey of Scotland in the early 1930s. However, two problems have arisen: (a) much storage space is necessary, since samples are currently being added to at the rate of 1500-2000 each year and (b) selection of samples appropriate to the research is not always easy, because of the large number of samples in store. The first difficulty has been overcome by the commissioning of a new soil store during the year and the second is on the way to solution by transfer of all available information from cards to computer store. Both developments should enable the soil store to be used much more effectively.

Four items of equipment acquired during the year should also materially facilitate research in different fields. Thus, a lanthanum hexaboride gun has been fitted to the scanning electron microscope to improve brilliance and contrast for non-conducting specimens—e.g. biological materials—and to yield more accurate electron microprobe results for low-atomic-weight elements. Addition of a Guinier-Lenne camera to the X-ray diffraction equipment permits structural information to be recorded continuously as samples are heated, thus ensuring that no tranformations go undetected. With a differential scanning calorimeter, now installed, accurate enthalpy measurements can be made up to about 750°C instead of the semi-quantitative information obtainable with earlier equipment. Finally, a dual ocular system has been fitted to the stereo-plotter so that two operators can consult on problems of interpretation and other personnel can be trained in use of the instrument.

Specialized techniques have been used to examine samples from other departments and those received from outside bodies that are relevant to current projects. Close connections have been maintained with the Forestry Commission, the Highlands and Islands Development Board, the Nature Conservancy, the Scottish Development Department and various other organisations, particularly in relation to the survey and utilization of peat. The responsibility of the Institute for the collection and dissemination of information and advice on peat resources and their development involves answering many requests for information from individuals and organisations.

The department suffered a great loss during the year through the sudden death of Dr Andrew S. de Endredy on 6th February, 1976. Although not a member of staff, Dr de Endredy had participated, between FAO contracts,

in work of the department for many years. A brilliant chemist with very wide interests, Dr de Endredy's encyclopaedic knowledge of chemistry and soil science were of great value to members of staff in the course of their duties and he will be sadly missed. Several of his publications emanated from the Institute; indeed, the last[73] has still to appear.

The department was pleased to welcome during the year: Mr M. Reda, College of Agriculture, University of Riyadh, Saudi Arabia, who spent some time studying Saudi Arabian soil clays; Dr N. Morandi, Istituto di Mineralogia e Petrografia, Università de Bologna, Italy, and Mr H. Shadfan, Institut für Bodenkunde und Standortslehre, Universität Hohenheim, Germany, who both studied magnesian minerals; and Mr A. M. Abbass, Soil Survey Division, Wad Medani, Sudan, who was given training in techniques used to characterize profile samples. Dr N. Güzel, Department of Soil Science, Cukurova University, Adana, Turkey, has just commenced a study of some Turkish soils using specialized mineralogical techniques.

Members of staff have attended, *inter alia*, the Centenary Meeting of the Mineralogical Society and the Clay Minerals Group meeting associated therewith; the 10th X-ray Analytical Conference; the 4th Conference of ARS Electron Microscopists; a Conference on Ion-Exchange Electrodes; the First European Symposium on Thermal Analysis (in the organisation of which members of staff were involved); and meetings of the British Ecological Society and the Mires Research Group. The Institute acted as hosts for the 1976 meeting of the Forestry Research Group which, in addition to visiting the Institute, made a tour of the forest soils fertilizer experiments in Scotland.

Mr R. A. Robertson attended, by invitation, a meeting on Peat Classification in Helsinki, Finland, in May and participated in the 5th International Peat Congress, in Poznan, Poland, in September. The Third International Symposium on Analytical Pyrolysis in Amsterdam was attended by Mr J. M. Bracewell who presented an invited paper[74] and acted as Chairman at one of the sessions.

CHEMISTRY AND MINERALOGY

During the year several thousand soil samples were transferred from various places of storage to the new soil store. This major operation was fortunately able to be carried out without serious dislocation of the work of the department. 101, 801

Chemical. Systematic chemical and physical studies have been completed on profile samples collected during 1973 and on a number of high-priority samples collected during 1974 and 1975. Analytical study of the remainder of the 1974 profiles is well advanced and the 1975 samples are being prepared for analysis. A chapter on the results of systematic laboratory studies has appeared in the Soil Survey Memoir covering the Perth, Arbroath and Dundee area (Sheets 48, 49). 101, 801

Seasonal variation in major-element content of ground-water continued to be monitored in a cut-over peat bog. Because of the dry summer, water levels have been very low, and calcium, magnesium, silicon and aluminium

contents during June, July and August were more than twice as high as in the previous year. Seasonal soil-atmosphere variations in surface horizons of cultivated soils representing the main soil Associations in north-east Scotland are also being examined by the equipment and techniques mentioned in last year's Report. The highest carbon dioxide (14·4 per cent) and lowest oxygen (1·2 per cent) contents in poorly drained soils have been recorded in the heaviest textured soil—namely the A_p horizon of the Birness Series of the Tipperty Association, which has a clay content of 30 per cent, a medium sub-angular blocky structure and a slightly plastic consistency.

101, 108, 111, 801, 5703

X-ray fluorescence spectrometry is proving to be of value in the determination of trace amounts of several elements. The smallest detectable amount of titanium in artificial mixtures with cellulose was 0·2 ppm and amounts of 2-3 ppm have been successfully measured in plant materials. Sulphur in feeding stuffs has also been determined in the range 0·1-0·3 per cent. A paper describing the determination of small amounts of chlorine and bromine in plant materials was presented at the 10th X-ray Analytical Conference in Edinburgh. 104, 107, 613, 5703

In collaboration with the Department of Spectrochemistry, a new technique for treatment of soil and mineral samples to give a solution that can be used for determination of both major and minor elements is being assessed. The method involves fusion with lithium metaborate followed by dissolution in dilute nitric acid. 107, 201

Thermoanalytical. Thermoanalytical techniques, particularly differential thermal analysis (DTA) and thermogravimetry, have many uses in mineralogy[1, 75], and are extensively exploited within the department for both systematic studies and research. DTA has recently been employed along with specific-surface-area measurement to examine the effect of sorbed anions, such as phosphate and sulphate, on the dehydroxylation of the iron oxyhydroxide goethite[2]. The heat of dehydroxylation of this and other iron oxyhydroxides is currently being measured by the differential scanning calorimeter with a view to examining in more detail the mechanism involved. Along with X-ray diffraction, DTA has been used to examine aluminium iodate complexes[3, 73] that may yield information of value in interpreting aluminosilicate formation from solutions containing mixtures of anions.

103, 105, 106, 107

Electronoptical. Scanning electron microscopy combined with electron probe microanalysis, which enables both morphological and chemical information to be obtained on surfaces, has shown that the gleyed surfaces of structural units (peds) of a clay soil have a smooth skin-like texture whereas individual clay particles are visible in ungleyed material from the interior[4]: chemical information was in reasonable agreement with previous chemical studies. Globular iron oxides covered surfaces of ochreous mottles and manganese-stained areas showed the typical sponge-like morphology previously observed for birnessite. 103, 109, 5703

Scanning electron microscopy, electron probe microanalysis and X-ray diffraction have been used, along with other techniques, to establish, in

conjunction with the Department of Microbiology, the natures of spines on spores and sporangia[5] and to examine the composition of cell walls[76].

107, 109, 507, 5703

Soil Mineralogy

Weathering converts rocks to soils, provides plant nutrients through degradation of primary minerals and forms the secondary minerals that not only retain nutrients in available form (or, in other circumstances, render them unavailable) but also determine a wide range of soil properties. In order to understand these phenomena, various particle-size fractions are separated, examined mineralogically and their behaviour compared with that of pure minerals. Less well-understood processes also occur in nature, however, and in connection with the conversion of atmospheric nitrogen to a form assimilable by plants, structural studies have recently been carried out, in collaboration with the ARC Unit of Nitrogen Fixation, on complex compounds containing molecular nitrogen[6]. 103, 104, 105, 107, 109

Sand Fractions. Although the clay fraction is generally regarded as the most important in determining soil properties, the coarser fractions are often by no means chemically inert—as is well illustrated by the cation-exchange characteristics of sand fractions of soils developed on tills derived from andesites and basalts of Old Red Sandstone (Devonian) age[7, 8]. Sand fractions of serpentine-derived soils show a high content of certain metallic cations and weathered micaceous material present in these contains relatively large amounts of total and acid-extractable nickel which may have accumulated through pedogenic weathering. Minerals such as nickeloan pyroaurite, which is stable in the rock but unstable in the soil[9], may well have contributed.

101, 103, 104, 207, 801

Potassium depletion from the centres, rather than from the peripheries, of flakes during the weathering of biotite appears to be relatively common. In some instances biotite is converted, on a sub-microscopic scale, to a kaolinite mineral; halloysite has also been identified as a weathering product. Collaborative studies with the Department of Spectrochemistry, involving Mössbauer spectroscopy, on the weathering of hornblende indicate that ferrous iron is lost preferentially from certain lattice sites and that conversion to the ferric form in this structure is difficult[10]. A device, constructed by Technical Services, for obtaining X-ray powder diffraction patterns from very small areas of thin sections is being used to examine the pedogenic weathering of felspar: it is giving satisfactory results.

103, 104, 109, 207, 901

Among soils examined from other countries, those from Elephant Island, British Antarctic Territory, proved particularly interesting since they contained an unusual phosphate mineral apparently formed through reaction of soil minerals with extracts from bird manure[11]. 103, 104

Clay Fraction. This fraction because of its small size and large surface area usually has a disproportionate effect on surface properties and much of the work of the department is geared to a better understanding of the

minerals present and their properties. Systematic clay mineralogical studies are performed on profile samples provided by the Department of Soil Survey and the results are described and collated in the appropriate Memoirs. During the present year a description of the clay mineralogy of the soils of the area around Perth, Arbroath and Dundee has appeared.

103, 105, 107, 801

Halloysite occurs widely in soils of north-east Scotland and is associated with a wide range of rock types, from acid to basic. It is possibly therefore a relic of an earlier weathering cycle (Tertiary or interglacial) rather than a product of recent pedogenesis[77]. Since the gibbsitic soils of the Southern Uplands[78] and of the summit areas of the western Cairngorms may have a similar origin, preglacial phenomena may have had a more prominent effect in determining soil mineralogy than hitherto appreciated. 103, 104, 801

The clay mineralogy of a representative selection of rocks of the Orkney Islands reveals that sandstones tend to contain mica and highly crystalline kaolinite, possibly of diagenetic origin, whereas calcareous flags often contain chlorite and interstratified vermiculite-chlorite. The clay fraction of a peaty podzol developed on till derived from chlorite schists near Loch Awe, Argyllshire, contained as much as 15 per cent titanium in the form of the oxide anatase[12]. 103, 104, 801

As in previous years, the clay mineralogy of various foreign soils (from the German Federal Republic, Egypt, Saudi Arabia, Turkey and Poland) has been examined for comparison with that of Scottish soils. The Polish soils contained three-component interstratifications of mica, vermiculite and smectite, which are difficult to identify on X-ray powder diffraction patterns. Since such three-component minerals may occur quite widely in soils, patterns for various compositions and degrees of randomness have been computed: these greatly aid in identification[79,80]. A number of clay samples, submitted by the off-shore oil industry, have given information of considerable value in connection with the behaviour of specific clay minerals under particular conditions.

101, 103, 105, 106, 107, 109, 207

Clay: Organic Matter Complexes. Complexes of metal salts with monocylic polyethers are relevant to the study of ionic transfer through cell membranes: for this reason the structure of a calcium crown ether complex has been determined[81]. 105

Studies on the weathering of chlorite minerals in Scottish soils[82] have suggested that ferruginous types may be susceptible to attack by organic acids[83]. Attempts to convert chlorite to vermiculite by heating beyond the dehydroxylation temperature of the brucite layer and then extracting with hydrochloric acid have been partially successful for magnesian chlorites, but less so for ferruginous species. The changes occurring on heating are being followed structurally using a Guinier-Lenne X-ray diffraction camera and the oxidation state of iron is being studied by Mössbauer spectroscopy.

104, 107, 203

Surface Properties of Soils and Clays. The crystal morphology of hollow rods generally accepted for akaganéite—beta ferric oxyhydroxide—is not

supported by specific surface area measurement and pore-size distribution as determined by gas adsorption techniques. However, an alternative morphology of solid rods is consistent with the findings of high-resolution transmission electron microscopy. Studies on pore-size distribution in allophanic clays, which demonstrated the occurrence of micropores less than 1 nm in size[84], have now been extended to Scottish soil clays known to contain appreciable amounts of non-crystalline inorganic material.

101, 103, 105, 106, 109

Release of considerable amounts of hydroxyl ions into a fluoride solution is normally associated with the presence of non-crystalline inorganic material. Detailed investigation of the reaction has shown that aluminium is particularly important in determining the amount of hydroxyl groups released by natural and synthetic mixed gels and crystalline minerals[13, 14]; the role of silicon and iron is currently being further investigated.

101, 105, 5701, 5703

Organic and Biological Materials. Rapid pyrolysis of soils followed by gas chromatographic separation of the volatile products and subsequent identification of these by mass spectrometry can be used to classify the organic matter associated with various types of soil. Thus, the surface organic horizons of podzols yield abundant methoxyphenols, derived from lignin, whereas the mineral A horizons give a predominance of dihydropyrone. Organic matter translocated to iron pans and B horizons yields benzonitrile, acetophenone, naphthalene and increased amounts of benzene[15]. Mor humus produces large yields of furan-ring compounds, whereas mull humus gives rise to increased amounts of pyrroles[15] and a compound recently identified with the cyclopentenone produced on pyrolysis of polymaleic acid —a substance synthesized by the Department of Soil Organic Chemistry as a model compound for fulvic acid. Recent improvements in technique include the use of open tubular gas chromatograph columns that provide improved separation of pyrolysis products. 101, 108, 301, 801

A numerical index, based on the relative abundances of various heterocyclic compounds in pyrolysates, correlates well with the base status and the abundance of organomineral complexes in soils containing mull humus[74]; moreover, it has been of use in confirming the existence of a sequence in New Zealand soils[16]. In collaboration with the Department of Soil Organic Chemistry, gas chromatography and mass spectrometry have also been employed to separate and identify trimethylsilyl derivatives of phenolic and carboxylic acids. 101, 108, 301, 801

The structure of the growth inhibitor maleic hydrazide, as determined by single-crystal X-ray diffraction techniques, has enabled an assessment to be made as to its mode of action[17, 18].

PEAT AND FOREST SOILS

Peat Survey and Evaluation

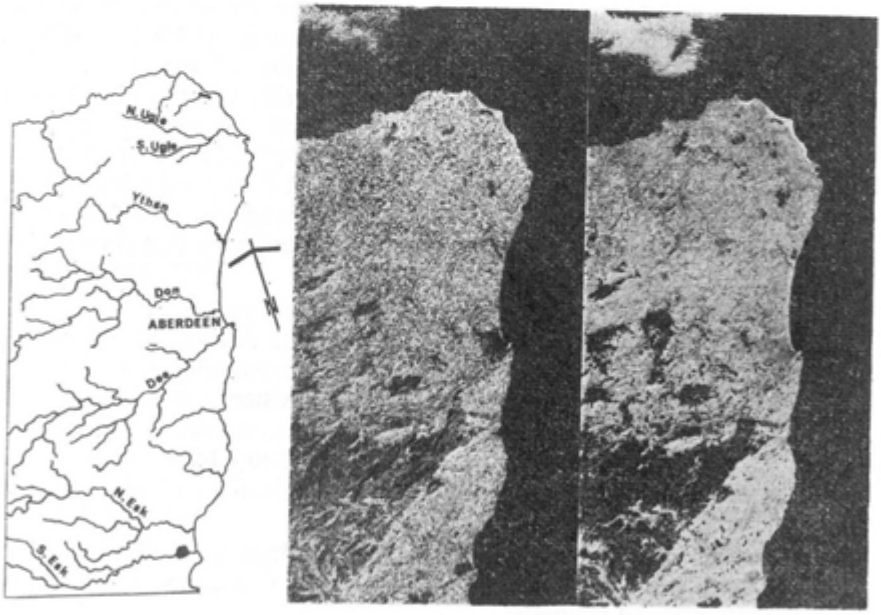
Deep peat, which covers some 800,000 ha (2 million acres) or 10 per cent of the area of Scotland, is not only a medium that could be more intensively developed for agriculture, forestry and other forms of land use,

but is also a very considerable reserve of raw materials for industrial and other purposes. Accordingly, peat survey, classification and evaluation are designed to provide information of practical as well as scientific importance. Results are incorporated in the Soil Survey Memoirs and in more detailed maps and reports for areas scheduled for development. A multilingual dictionary of peat terms published in 1973 has now been extended to include the Polish language[19]. 112, 113, 801

Survey techniques, including topographical, stratigraphical, botanical and photogrammetric studies, are also employed to support investigations on site capability[20], peatland drainage[21], bog cultivation and afforestation[22] and the production and utilization of peat for horticulture[23].

110, 111, 112, 114, 802

Detailed peat surveys of the mosses at Arden, Lanarkshire, Campbeltown, Argyllshire, and Easter Inch, West Lothian, have been completed during the year. Photogrammetric mapping using a stereo-plotter is assuming increasing importance in recording the nature and extent of peatlands. In Lewis and Harris mapping has mainly been on the scale of 1:25 000, but larger scales have been used for selected sites. Following last year's reconnaissance to collect ground information and samples, plotting of peatland types for Shetland has begun. 112



A B C

B and C depict, respectively, black-and-white prints of Bands 7 (infrared) and 5 (green) of the multispectral imagery observed by LANDSAT 1 space satellite orbiting at an altitude of 923.6 km over north-east Scotland on 11th March 1973. Before final photographic reduction the prints were scaled on the stereo-plotter to 1:1 000 000 to compare the accuracy of atlas detail at this scale (A). False-colour composite images of many areas of Scotland have been produced from film positives such as these together with those of Bands 4 (blue) and 6 (red and near infrared).

Research on photogrammetric techniques of mapping is concentrating on maximum computer processing with graphic output of results. A large number of programs has been written and a basic framework and system established for development of a peat data bank for Scotland. Not only can surface and bottom contours of bogs, isopachytes, etc., be plotted but plane areas, surface areas and volumes of peat deposits can be rapidly computed, thus greatly increasing throughput. 112, 703, 5703

The value of photo-interpretation and remote sensing techniques in peat survey is being thoroughly examined by assessing (a) the usefulness of different scales of photography from low-level aerial photography to satellite imagery and (b) the value of different types of film for different mapping purposes. Complete aerial photographic coverage of the Grampian Region is currently being undertaken on a three-year basis and the Institute shares in planning as well as having complete access to results. Black and white prints of about 80 per cent of the first year's programme are now available along with true-colour and false-colour photographs of selected areas. Colour composite slides and prints are also being prepared from satellite film, a variety of false-colour composite slides for much of the northern part of Scotland already being available. Results obtained by colour-enhancing a wide variety of peatland areas at different seasons are encouraging and indicate the technique may be useful in many forms of land-use mapping. 112, 902

A more comprehensive and meaningful system of peatland classification is being devised and applied, taking into account such characteristics as phytosociology, hydromorphology, chemistry and stratigraphy: the relative importance of these various factors is still being assessed. A provisional system has been applied in two areas, near Nairn and Stirling, and is being further tested on the Isle of Rhum. Efficient storage with easy retrieval and sorting of vegetational information collected in connection with peatland classification will be facilitated by computer techniques now being tested. 112, 5701, 5703

Pollen Analysis and Quaternary Research

Two sites, in Caithness and Kincardineshire, where peat bogs overlie thick deposits of marl, are currently being investigated in an attempt to elucidate the reason for this not uncommon phenomenon. Examination of pollen diagrams for two deep peat profiles from Wigtownshire has increased understanding of the vegetational and climatic history of south-west Scotland. Site-to-site comparison of trends in local vegetational history is facilitated by a graphical method of representing pollen stratigraphical assemblages by single points on a curve[85]. A general account of vegetational history and chronology in the Lowlands and Southern Uplands[24] of Scotland has appeared in a recent Monograph. 112, 113, 802

Further studies on the peat deposit cut by the line of the new A9 road at Slochd Pass, Inverness-shire, indicate that the embedded remains of pine trees do not occur in two separate layers, as envisaged by Lewis in 1911, but are scattered throughout a horizon 2·5 m thick. After the pre-Flandrian stage of development this moss grew slowly for 4-5 thousand

years within the relatively stable arboreal vegetation of the Caledonian forest. Subsequent anthropogenic and climatic changes ended the dominance of pine and allowed birch and moorland vegetation to increase. 112, 113, 802

Computer storage and statistical processing of pollen information is continuing and about 90 sites covering the whole of Scotland have been digitized on a 1: 633 600 scale. The flexibility of the digitization format allows maps of the whole or parts of Scotland to be produced at any desired scale and spatial analyses of selected sites to be undertaken. Work is progressing on production of isopoll maps depicting contours of equal pollen percentages based on the sum of individual pollen types. 113, 5703

Root and Moisture Studies in Peat

The physical conditions prevailing in peatlands require a considerable amount of amelioration before the land can be used for commercial purposes. The high moisture content (usually over 90 per cent on a wet-weight basis) of undrained peatland sustains a largely anaerobic soil profile capable of supporting only a specialized vegetational community of bog or heath plants. To carry agricultural or forestry crops the status of the peat has to be improved by lowering the water-table by some form of drainage. An experimental site at Lon Mor, Inverness-shire, has provided valuable information on the relationships between water-table depth[86], moisture: air ratios, soil aeration—as oxygen percentage—and plant growth in terms of rooting and total production of a crop of lodgepole pine. This has revealed that root development of this species is strongly correlated with oxygen content and is more influenced by adverse (winter) than by favourable (summer) conditions[87]. 110, 117

Tritiated water has been used to trace water movement at two afforested sites belonging to the Forestry Commission[88]. In a peaty gley at Kershope Forest near Langholm, water movement was closely related to the topography of the site and occurred in all horizons, whereas in deep peat at Flanders Moss, Lanarkshire, it was largely determined by the depth and spacing of the ditches, although a slow general movement also occurred down a slope 1 in 300. 110, 117

Glasshouse experiments, in collaboration with the Department of Plant Physiology, on the incidence of blossom-end-rot in tomatoes grown in pure peat substrates have been extended to include different levels of calcium as well as different moisture regimes. 114, 402

Nutrient Uptake from Forest Soils

Studies on the effect of soil type and fertiliser input on the rate of nutrient cycling through the soil-tree system have continued with the establishment at Kilmichael Forest, near Lochgilphead, of the sixth, and final, experiment in the series. These experiments now cover a representative selection of the bioclimatic sub-regions and soils in which Sitka spruce, the test species, is widely planted. The equipment developed to monitor nutrient movement in these experiments has been described[89].

Only one of the first five experiments has failed to show a growth response to applied fertilizer, although at some sites it has taken up to three years for

a significant response to develop. The trees respond both to the combined application of phosphorus and potassium and to the application of nitrogen alone. This apparent disregard of the law of limiting factors is further confused by the nitrogen response being almost eradicated when phosphorus is applied along with the nitrogen. Foliar nutrient levels have responded to the fertilizer treatments at all sites. 115

Nutrient movement in both litter fall and rainwater is being followed in these experiments. Rainfall collected above the canopies contains, per ha per year, 5-10 kg nitrogen, 0·02-0·04 kg phosphorus and 1·4-4·3 kg potassium; the comparable values at ground level are 8-19 kg nitrogen, 0·16-0·46 kg phosphorus and 10·8-35·6 kg potassium, much of which is believed to be due to true crown leaching. 115

The detailed response of Corsican pine to nitrogen fertilizer, including the rate of cycling, the uptake, accumulation and eventual re-use of fertilizer nitrogen, the build-up and subsequent decline of photosynthetic tissue and changes in photosynthetic efficiency, has now been documented[25, 26, 90]. Attention has also been given to developing methods that can be used by a forest manager to assess the nitrogen status of pines[27]. 117, 5701, 5703

In an experiment on a freely drained humus iron podzol, growth of mature Scots pine over a period of 40 years was found to follow variations in May rainfall, annual temperature and the May plus June rain of the previous year[28]. Four cycles, on periods of 4·4 to 42 years, were indentified on the pattern of tree ring widths and each could be matched to a cycle in one of the climatic parameters. Interestingly, the cycles in rainfall appear to be limited to the rainshadow of the Grampian mountains. Further examination[91] suggests that the influence on May-June rainfall of the previous year is through an effect on nitrogen uptake, probably working through nitrogen mineralization in the raw humus accumulated on the soil surface. A regression equation based on May rainfall and foliar nitrogen levels explained 94 per cent of the variation in ring widths over a ten-year period.
117, 701, 5701, 5703

Foliar analysis of lodgepole pine planted in a peat drainage experiment failed to show any improvement in nutrient status following canopy closure, consequent drying of the peat and rapid increase in rooting depth[92].
110, 111, 117, 5701, 5703

Nitrogen Mineralization in Peat and Mor Humus

Studies on different particle size fractions (separated by wet sieving) have been extended to include samples of flushed and unflushed blanket peat, which is richer in nitrogen and more highly decomposed that those previously studied. In all samples the nitrogen content of fractions in the 0·005-5 mm range increases (with consequent decrease in C:N ratio) as the particle size decreases, but the proportion of nitrogen mineralized on incubation remains small and fairly constant. The largest proportions of nitrogen mineralized are in coarse fractions (1-5 mm) of flushed blanket peat. 116

Samples of peat from contiguous planted and unplanted areas have been used to assess the changes occurring in peat on afforestation with lodgepole

pine. The upper horizons under trees have a lower calcium content and a higher acidity: these factors may account for the differences in rates of nitrogen mineralization and carbon dioxide evolution noted in last year's Report. 110, 111, 116, 5701, 5703

Long-term effects of lime and fertilizers on the chemical composition and nitrogen mineralization rates of mor humus continue to be examined in samples from a Scots pine experiment at Culbin (Laigh of Moray Forest). Incubation of samples of litter and humus from untreated and NPK-fertilized plots beneath polestage Sitka spruce at Fetteresso (Mearns Forest) revealed only a slight effect of fertilizer treatment on the amount of nitrogen mineralized but a marked change in the nature of the mineral nitrogen, accumulation being of nitrate rather than of ammonium. 115, 116, 117

2. SPECTROCHEMISTRY

Dr R. O. SCOTT

The work of the department continues to be divided into three interrelated categories: the investigation of the distribution of trace elements in soils, soil profiles and plant materials; the characterization of inorganic and organic components of soils; and the provision of an analytical service for the determination of trace elements in samples from other departments. The elemental coverage in the first category has been greatly widened by the use of spark-source mass-spectrometry, and to obtain a more sensitive and rapid method for the determination of selenium alternative methods such as cathodic stripping voltammetry are being investigated. Investigations of the forms in which metal-organic complexes occur in soils will be facilitated by the approval to purchase this year an electron paramagnetic resonance spectrometer. Dr B. L. Sharp, a new member of staff, is investigating the application of lasers for the analysis of samples of agricultural interest. For his work on Laser Excited Atomic Fluorescence, carried out at Imperial College, London, he has been awarded the Rank-Hilger spectroscopy prize for 1975.

Several visiting research workers have used the spectroscopic facilities. Dr J. V. Lagerwerff, United States Agricultural Research Service, Agricultural Research Center (West), Beltsville, Maryland, U.S.A., has been studying the formation of complexes of copper with soil organic matter; Dr Maria P. Hernandez, Department of Analytical Chemistry, University of Murcia, Spain, and Miss Jilla Khalighie, a former student of the National University of Iran, Teheran, Iran, and of Imperial College, London, are working on the development of atomic absorption methods of analysis; and Mr Stuart Forbes, an S.R.C. research student working towards the degree of Doctor of Philosophy of the University of Aberdeen, has completed the first year of a research project on stripping voltammetry for the preconcentration/determination of trace elements. Short term visitors have included Dr F. Palmieri, Instituto di Chimica, Agraria Della Universita Degli Studi di Napoli, Portici, Italy; Mr A. M. Abbass, Soil Survey Division, Wad Medani, Sudan; Mr M. O. B. Karrar, Government Geological and Mineral Resources Department, Khartoum, Sudan; Mr M. Reda, College of Agriculture, University of Riyadh, Saudi Arabia; and Dr I. Tunckale, Ministry of Forests, Poplar and Fast Growing Trees Research Institute, Turkey.

The department was represented at two international conferences. Dr A. M. Ure presented a paper at the 7th International Mass Spectrometry Conference in Florence, Italy, and Dr B. A. Goodman presented two at the International Conference on Applications of the Mössbauer Effect in Corfu, Greece. Contributions were made by members of staff at meetings of the Radiochemical Methods Groups and the Analytical Division of the Chemical Society. Meetings of the DOE Standing Committee of Analysts (Group 8.0; soils and sewage sludges), the Analytical Division of the Chemical Society, the Clay Minerals Group of the Mineralogical Society, the Scottish

Direct Reading Spectroscopy Group (now incorporated into the Association of Scottish Industrial Analysts), and the Interservices/DTI Panel on Spectroscopy were also attended.

Trace Elements in Soils, Plants and Biological Materials

Although the main extracting agents in use for evaluating the trace element status of soils continue to be 0.5 M acetic acid, neutral 1.0 M ammonium acetate and 0.05 M EDTA, some preliminary work using diethylene-triamine pentaacetic acid (DTPA) as a soil extractant has been carried out. Using the same concentrations and conditions of extraction as employed with EDTA, the results show that DTPA extracts slightly less aluminium, chromium, cobalt, copper, iron, manganese, nickel and zinc and considerably less lead, titanium and vanadium from cultivated Scottish soils. The amounts of trace elements extractable by DTPA, 2-ketogluconic acid, a common metabolic product of rhizosphere microorganisms, and the other extractants in relation to pasture herbage uptake are being investigated. 201

Soils and Soil Parent Materials. The determination of trace elements in selected soil profiles sampled by the Department of Soil Survey has continued. Work on soils from the area covered by Sheets 1, 2, 3 and 4 and part of 7 (Kirkmaiden, Whithorn, Stranraer and Wigtown) has been completed and work on the areas covered by Sheets 32 and 24 (Edinburgh and Peebles), Sheet 84 (Nairn and Cromarty) and Sheets 40 and part of 41 and 32 (Kinross, Elie and Edinburgh) is in progress. 101, 201

Investigations on the distribution of trace elements in soil profiles with iron and manganese pans have continued. A paper dealing with the characterization of iron in iron pans using Mössbauer spectroscopy is awaiting publication[93] and another, confirming these findings by the use of different chemical extraction techniques on the same pans, is in preparation. 201, 203

The work reported last year, carried out in collaboration with the Department of Soil Organic Chemistry, on the distribution of trace elements in humic and fulvic acids and their sub-fractions, supported by electron paramagnetic resonance studies on the form in which they occur, has been prepared for publication. 201, 203, 307

Collaborative studies with the Departments of Pedology and Soil Survey on trace elements in peat profiles have continued. Eighty-five samples from ten peat profiles from Wigtownshire and nineteen samples from four profiles from the Soil Survey Sheet 84 (Nairn and Cromarty) have been analysed for total barium, copper, iron, manganese and strontium. The results of these analyses are in agreement with the findings previously reported (Ann. Rept. No. 44, 1973-74) that the copper content generally decreases with increase in depth but increases, often sharply, close to the mineral parent material. In contrast the manganese content increases down the profiles. 101, 112, 201

A study of trace elements in soil profiles representing a freely drained and very poorly drained series of both the Insch and Countesswells Associations sampled three times at about ten year intervals, air dried, stored and

all analysed this year has shown that in the freely drained profiles little change has occurred in their extractable contents over a period of twenty years in both the topsoil and subsoil horizons. In the comparable horizons of the very poorly drained profiles, however, there have been considerable changes, particularly in the extractable-manganese contents. It has not yet been established whether these are a result of oxidation-reduction reactions in the field caused for example by fluctuations in the height of the water table prior to sampling or have arisen during storage over the period considered. 201

From the analysis of a limited number of soils the range of selenium contents in Scottish soils appears to be from $<0{\cdot}01$ to about 0·5 ppm with a mean content of about 0·2 ppm. 201

Soil Status and Plant Uptake. During the year the number of requests by the Department of Soil Fertility for the analysis of samples from areas with suspected nutritional deficiences in plants or animals has remained about the same, but those concerned with heavy metal pollution problems have increased. Samples as diverse as sewage sludges, distillery wastes and soils contaminated by pig slurries or spoil from lead mining have been examined for their total and extractable trace element contents. Soils treated over a period of at least 50 years with distillery waste have been found to contain EDTA-extractable copper contents of up to 100 ppm with some of the pasture herbage levels as high as 40 ppm, possibly due to residual contamination on the plants. Soils treated with pig slurry for periods of up to ten years have been found to contain up to 20 ppm EDTA-extractable copper. In order to obtain information on the fate of copper applied to soil in these forms, soil profile samples have been taken this year in selected areas where such wastes have been applied for a long period. 201, 609, 610

The determination of total, acetic acid-, ammonium acetate- and EDTA-extractable contents in soil profile samples from the Department of Soil Fertility experimental plots covering a wide range of soil parent materials and drainage conditions has been completed. The results from the 29 plots are being assessed. The analysis of the related plant samples has been delayed, but it is anticipated that this will be resumed when work on the sewage sludge experiments is completed. 201, 202, 609

The examination of surface soils and plants from the Department of Soil Fertility field experiments has continued. The total trace elements in about 30 and the 0·05 M EDTA-extractable copper and manganese in about 250 surface soils have been determined. About 70 plant samples from these experiments have been analysed by the chemical-concentration method for a wide range of elements and about 800 for copper and manganese. In confirmation of the earlier work it has been shown that the addition of 2 lbs of cobalt sulphate per acre (2.24 kg ha^{-1}) is sufficient to raise the cobalt content of herbage to a level adequate for the healthy growth of stock. 201, 202, 609

In collaboration with the Agricultural Development and Advisory Service of the Ministry of Agriculture, Fisheries and Food the analysis of sewage sludges, sludge-treated soils, and crops from sludge-treated plot experiments have continued. Plot soils at one site sampled eight years after treatment with sludges containing high contents of chromium, copper, nickel and zinc

are currently being examined for extractable trace elements. Ammonium acetate-extractable trace elements in the soils from thirty-two plots and in the sludges applied have been determined. The total selenium contents of the sludges ranged from 1·6 to 7·0 ppm (mean 2·9 ppm), and the mercury contents up to 13 ppm. The outstanding 260 crops sampled by ADAS have now all been analysed by the concentration method. Unfortunately many of these samples appear to have been slightly contaminated by soil. In June this year the grass at one site was sampled by Institute staff and it proved possible to select timothy grass at the headed stage as a plant species common to all the treatments. These samples were fortunately collected before the 1976 drought conditions had affected the site. The analysis of these samples is well in hand and their iron contents of less than 100 ppm in the dry matter indicate that the samples are free from any significant soil contamination. 201, 202

Field experiments on the uptake of selenium added as sodium selenite or selenate to different soil types were started in the spring of this year in collaboration with the Department of Soil Fertility and the first plant and soil samples have been collected for analysis. 201, 202, 609

Miscellaneous samples analysed have included soils from the Philippines and St. Helena sent by the Ministry of Agriculture, Fisheries and Food, soils and minerals for Dr El-Kholy, Sana'a University, Yemen, and animal livers from Dr Suttle, ADRA Moredun Institute, Edinburgh. In addition, samples of plastic materials have been analysed for the Grassland Research Institute and molasses and pig feed for the Rowett Research Institute. Plant samples analysed from various sources include conifer needles from the Peat and Forest Soils section of the Department of Pedology, 13 standard reference plant materials from ORSTOM (Office de la Recherche Scientifique et Technique Outre-Mer, Bondy, France), and blue gum (eucalyptus) leaves from the Department of Soil Science, University of Aberdeen. 5205, 5206

Spectrochemical Methods of Analysis

The established methods for multi-element analysis of soils and plant materials have remained unchanged. In the chemical concentration procedure for the analysis of plant materials, contamination from impurities in the platinum crucibles used for the sodium carbonate fusion of the ashed sample has been causing concern. Two alternative crucible materials, boron nitride and zirconium metal, have been tested as possible alternatives, but under the ignition conditions presently available neither appears to be entirely satisfactory.

A sample from Papua New Guinea (leaves of *Eurya tigang*, member of the Theaceae), milled in Australia in a tungsten carbide disk mill, provided an opportunity for cobalt and tungsten contamination of the sample, revealed by spectrochemical analysis, to be confirmed by the Cambridge S4 stereoscan. 109, 5205

Arc Emission. No changes have been made during the year to the cathode-layer d.c. arc technique used for the analysis of soils, soil extracts and plant materials. Investigations on the use of the high-current arc (Ann. Rept.,

No. 44, 1973-74) to lower the limit of determination of trace elements in soils have continued, and the claim of some American workers that helium is preferable to argon as a sheathing gas has been tested using the triple gas-jet apparatus. Although some line intensities were greater with helium, the zinc and beryllium emissions were greatly reduced, the latter effects probably resulting from the better exclusion of air by argon as indicated by lower CN emission. No advantage could be found for using helium that would outweigh its higher cost. To reduce the incidence of transistor failure the 20 A stabilized high-current d.c. arc supply is being modified by adding further transistor banks which will also increase the output to 30 A. 205

Direct Photometry. The E789 Polychromator with the cathode-layer d.c. arc source has been used to analyse about 6000 samples of soils, plant ashes and chemical concentrates. Although the instrument showed excellent stability over the period 1970-75 (Ann. Rept., No. 45, 1974-75), lately its sensitivity has increased by about 10 per cent. A small change of the order of one per cent in the EHT supply to the photomultipliers could account for this and the instrument is being modified to monitor this voltage precisely. 205

About 300 chemical concentrates of acetic acid-extracts of soils have been analysed using both photographic recording and direct reading. By both methods the results for cobalt (0·01 to 3·0 ppm in the soil), lead, molybdenum, titanium, vanadium and zinc are in good agreement. For nickel and chromium, the results by direct reading are slightly lower than by photographic recording, the divergence probably being caused by the application of background correction with direct reading. 201, 205

The Hilger Medium Direct Reading Spectrograph continues to be used especially for the determination of boron and other elements in the ash of plant materials by the rotating-disk technique. 202, 205

Flame Emission. The number of samples analysed by the three-channel laboratory-built flame photometer has risen again this year, with calcium and potassium each about 28000 and sodium about 18000. 5206

In collaboration with the Department of Pedology promising results have been obtained in developing a method for the determination of major and trace elements in rocks and ignited soils using a lithium metaborate fusion of the sample followed by dissolution in 3 per cent nitric acid. Aluminium, potassium and sodium are determined by flame emission and calcium, magnesium, silicon and chromium by atomic absorption. It should be possible to carry out with adequate precision and accuracy the total analysis of such samples, including the determination of iron, manganese and titanium by flame methods when a suitable instrument is installed. 101, 206

Atomic Absorption: Flame Techniques. There have been no developments since last year in the flame atomic absorption techniques employed. The workload on the Techtron AA4 instrument is now approaching the maximum possible. Besides being used for about the same number of deter-

minations of manganese and zinc as last year, it has had to deal with increased numbers for calcium (9000), for magnesium (18000), and for copper (1500). 5206

Atomic Absorption and Fluorescence: Electrothermal atomization. An account of the method, mentioned in previous reports, for the determination of cadmium in plant material and soil extracts by atomic absorption, using carbon-rod atomization of dithizone-in-chloroform extracts, has been published[94]. The atomic absorption channel of the instrument used for this work has now been adapted for the determination of lead and a non-dispersive atomic fluorescence channel, using a Philips Spectrum Lamp L59-305-015 and a solar-blind photomultiplier tube (Hamamatsu R166), added for the determination of cadmium. With this instrument lead and cadmium, extracted together by dithizone-in-chloroform, are determined simultaneously. Lead in the range 0·05 to 2 ppm and cadmium in the range 0·001 ppm to 0·02 ppm in the original aqueous solution can be determined (0·5 to 20 ppm lead and 0·01 to 0·2 ppm cadmium in oven-dry plant material). The flexibility and linearity of the atomic fluorescence method allow the determination in solution of cadmium up to at least 2 ppm by adjusting the channel gain. Reproducibility and accuracy are good for both elements and excellent agreement for lead in NBS Orchard Leaf sample No. 1571 has been obtained. 206

A short note has been published[95], demonstrating the effectiveness of sulphuric-nitric acid digestion and potassium permanganate oxidation in dissolving mercuric sulphide for the atomic absorption determination of mercury; a dissolution procedure which has been questioned in the literature. The note also mentions the depressive interference on the mercury signal which occurs when the iron content is very high (about 25%). This is of little importance for most soils but can affect the analysis of some rocks and minerals.

A paper reviewing practical developments in atomic fluorescence spectroscopy has been published[29]. 206

Radio-frequency Plasma Emission. With the aid of a recently acquired low-power radio-frequency plasma, an investigation has been undertaken of the determination in soil extracts of cobalt, molybdenum and other elements of biological importance. With the limited equipment available, the detection limit for molybdenum has been found to be about 0·01 ppm in solution. 201, 206

Laser Spectroscopy. Laser equipment provided by the Science Research Council, the Agricultural Research Council and the Royal Society is being used at the University to investigate the possible application of lasers to agricultural problems. Preliminary work has included their use as excitation sources for atomic fluorescence spectroscopy[30] and equipment is being assembled to study, by remote sensing, the distribution of species such as SO_2, NO_x and pesticides in agricultural atmospheres. A paper on the applications of lasers to analytical chemistry has been published[31]. 206

Other Methods of Trace Element Analysis

Fluorescence Spectroscopy. The fluorescence method for the determination of selenium (Ann. Rept. No. 40, 1969-70) has been modified to lower the limit of determination in oven-dry plant material from about 0·03 ppm to 0·006 ppm. Five grams of the sample are ashed in a silica sample holder using the oxygen-flask combustion technique and the selenium absorbed in a collecting solution consisting of a mixture of 25 ml of a saturated aqueous solution of potassium persulphate and 10 ml of concentrated sulphuric acid. Using this combustion and collection procedure the recovery of selenium has been increased from about 70 to 90 per cent, and the precision improved. The collecting solution is treated with concentrated hydrochloric acid to destroy excess persulphate, diaminonapthalene is added, the selenium complex extracted with dekalin and the fluorescence measured. The coprecipitation stage with arsenic is now omitted. 206

Cathodic Stripping Voltammetry. An alternative method for the determination of selenium is being developed in collaboration with the Department of Soil Fertility using cathodic stripping voltammetry. Sub-nanogram quantities (0·0005 ppm in solution) of the element have been detected after removal of interfering metal ions, such as those of copper and lead, by ion-exchange chromatography. Other digestion techniques for plants and soils, in preference to the oxygen-flask combustion procedure, are currently under investigation. 206

Spark Source Mass Spectrometry. The tentative method for the analysis of soils and rocks, outlined in last year's report, has been developed to provide quantitative determinations (reproducibility ± 10% to ± 25%) of some 50 trace elements and semiquantitative values (reproducibility ± 50%) for the major elements calcium, iron, magnesium, manganese, potassium and titanium. In any one sample the elements determined may range from about 0·1 ppm to several per cent. By supplementing this information with the contents of a small number of elements, derived using other techniques, a comprehensive survey of the elemental composition of a soil or rock can be obtained for 62 elements. Because of the large amount of information obtained it is difficult to make comparisons between soils. Methods of using the data to provide a display of the elemental content in a form which makes these comparisons possible visually are being investigated. A report on the analysis, by this technique, of ten Scottish arable top-soils derived from different parent materials is in preparation. 201, 205

Improvements in the method have arisen mainly from progress made towards establishing relative sensitivity coefficients (RSCs) by the analysis of a wide range of standard rock samples and of synthetic powder standard samples. An essential prerequisite for the determination of accurate RSCs is the elimination of superpositional interference effects and effective techniques for their correction, first demonstrated for the rare earth elements[32], are now being applied to other elements. An account of these techniques is in the press[96]. By the use of these RSCs the analytical precision for most elements is now approaching the values achieved for the reproducibility.

For the analysis of plant or biological materials and 8-hydroxyquinoline-tannic acid-thionalide chemical concentrates it has proved necessary to use another internal standard in addition to indium because of the coincidences of chloride molecular ions of potassium and calcium with the indium isotope lines. For this purpose iridium (as ammonium chloroiridate) has been found suitable. Other developments include the routine use of an automatic spark-gap control unit and an ion-beam chopper for short-exposures. The latter ensures that a large enough weight of sample is consumed for representative sampling of the electrode by the spark. 205

Molecular Spectrometry of Soil Constituents

Optical Absorption Spectrometry. Work at the Institute has developed infrared spectroscopy into a powerful tool for characterizing the composition, structure and reactions of both organic and inorganic soil constituents, and a general survey of its application in surface studies of clays and oxides has been published[33]. A recent development in this field is in the study of the surface reactions of iron and aluminium hydroxides, which are important adsorption sites in natural soils. As a result of this work, the nature of the adsorption complexes formed by phosphate and fluoride on the goethite surface are now well understood[34], and similar processes have been shown to be involved in the adsorption on many other ions, including oxalate, benzoate, sulphate, nitrate and chloride[97, 98], as well as natural fulvic and humic acids[99]. In each case only singly co-ordinated surface hydroxyl groups are partially or completely replaced by the adsorbed anions. Such hydroxyl groups are regularly distributed over the whole surface of goethite, but are restricted to the edge faces of gibbsite, and only these are involved in anion replacement reactions[99, 100], although in acid conditions and at higher concentrations fulvic acid also covers the other faces of gibbsite, probably by hydrogen bonding interactions[99]. 207

Combined with Mössbauer studies, infrared spectroscopy has proved valuable in characterizing nontronites and has been found to give information both on composition and on the extent to which iron replaces silicon in their structure[35]. Iron atoms in these and other iron-rich smectites can undergo reversible reduction and oxidation, and here again a combination of Mössbauer and infrared studies gives insight into the extent of reduction and the sites involved. A paper is in preparation comparing the effects of two commonly used reducing agents, hydrazide and dithionite: the latter is the more powerful and appears to achieve a partial conversion of nontronite to the iron-rich mica, glauconite. Reduction of iron in layer silicates is likely in water-logged soils, and may account for their blue colour. 203, 207

The highly reactive hydrated aluminium silicates, allophane and imogolite, were first recognized in volcanic ash soils, but related or identical materials are now known to be present in the B horizon of freely drained Scottish soils. One reason for slow progress in their recognition and investigation has been the lack of convenient techniques for their characterization. It has now been found that imogolite exhibits a distinctive infrared adsorption band that allows its recognition when associated with allo-

phane[101]. A chapter[36] on general aspects of vibrational spectroscopy applied to mineralogy has now appeared as part of a book on physical methods of mineral analysis and the report on a nickel-rich basic carbonate formed in serpentinite has been published[9]. 103, 104, 207

Infrared spectroscopy continues to play an important role in following the fractionation of soil organic matter, in support of the work of the Department of Soil Organic Chemistry. One fraction that is of particular interest because of its biological activity and its role in podzol formation is a water-soluble acidic brown polymer, which has now been shown to resemble polymaleic acid closely in its chemical and spectroscopic characteristics[37]. This constitutes a completely novel proposal for the structure of fulvic or humic acids, and, if correct, could rejuvenate their chemical investigation. Other aspects of these long-standing collaborative studies in soil organic matter are being prepared for publication. One important contribution of infrared spectroscopy to this field is the recognition of unexpected impurities that are difficult to exclude completely in the course of complex fractionation procedures. In less experienced hands, however, the absorption bands of contaminants such as silica gel, carbonates, and plasticizers have been misinterpreted in terms of soil organic structures, and such misinterpretations have even been incorporated in a standard text in soil chemistry. It is important, therefore, to correct such errors at an early stage, and a second critical note drawing attention to them has been submitted for publication[102]. 208, 304

Infrared spectroscopy has shown that long-chain polyphosphate is a common component of fungal walls of the Mucorales group, where it is associated with chitosan[76]. 709, 208, 507

Mössbauer Studies. Investigations of relevance to Scottish soil-forming minerals have been continued and papers on the assignment of sites in dioctahedral micas[38], the interpretation of the spectra of biotites[39], the weathering of a hornblende[10] and the structure of nontronite[35] have been published. Work on nontronites and the products resulting from their treatment with various reducing agents is continuing. A study has been initiated on chlorites with a view to identifying the location of iron within the structure and, as an aid to the assignment of these spectra, some artificially vermiculitized samples have also been investigated. With the aid of facilities at the Department of Natural Philosophy of the University of Aberdeen, iron pan samples, further to those reported last year, have been investigated in the temperature range 4·2 to 77°K, and a paper on the characterization of the secondary iron in pans derived from Scottish podzolic soils is awaiting publication[93]. Some theoretical work has been started on the assessment of the influence of isomorphous substitutions in silicate minerals on their Mössbauer parameters[103]. 104, 201, 203, 207

The study of plants grown in nutrient solutions enriched with ^{57}Fe, undertaken last year in collaboration with the Department of Plant Physiology, has been extended with the use of the low temperature facilities at Aberdeen University. Although the identification of the principal iron-containing compounds has not yet been possible the presence of iron as ferritin in

appreciable amounts is excluded by the low temperature results. 203, 401

Investigations of the changes in the nature of iron-humic acid complexes with pH have been initiated using complexes containing added ^{57}Fe and having high organic matter:metal ratios. Preliminary experiments on suspensions have shown that the oxidation state of iron is pH dependent, being Fe^{3+} above about pH 4 and Fe^{2+} below about pH 2. Reversible changes from one form to another can be accomplished by variation of the pH. 203, 307

Electron Paramagnetic Resonance Studies. Results of investigations on the composition of soil humus[40], on the bonding of vanadium in complexes with humic acid[41], and on the occurrence of copper-porphyrin complexes in soil humic acids have been published[42]. A family of computer programs has been written to enable the simulation of EPR spectra for powder samples using a variety of spin Hamiltonians. These have proved extremely valuable in obtaining reasonable interpretations of experimental spectra. In spite of these developments interpretation of the spectra from the molybdenum-humic acid system has not yet proved possible and further experiments are being carried out using ^{93}Mo and ^{95}Mo isotopes. A project aimed at a study of the bonding of copper with fulvic acids has been started in collaboration with Dr J. V. Lagerwerff, a visiting research worker, but as yet no definite results are available. 203, 305, 307, 703

Investigations of the forms of metal complexes in the xylem exudates from sunflowers, in collaboration with Dr R. Graham, a visiting research worker at the Department of Botany of the University of Aberdeen, has illustrated the potential applications of EPR to this type of problem. 203

3. SOIL ORGANIC CHEMISTRY

Dr G. ANDERSON

The department has continued its investigations on the origins, chemical composition and properties of the major components of soil organic matter, and on the factors influencing their synthesis and stability in the soil. Physiological studies are carried out on the effects of the components on the growth and nutrition of plants and plant tissues. A number of collaborative chemical and biochemical investigations have been made with other departments on organic materials from soils, plants and micro-organisms. A technical dictionary of peat terms, in English, German and Russian, published in 1973, has now been extended to include Polish[19].

A visiting research worker, Mr S. Murayama, Department of Soils and Fertilisers, National Institute of Agricultural Sciences, Tokyo, is studying methods for following organic transformations in soils.

Dr G. Anderson presented an invited paper[104] at a symposium on the role of phosphorus in agriculture, jointly sponsored by the Tennessee Valley Authority, the American Society of Agronomy, the Soil Science Society of America and the Crop Science Society of America, at Muscle Shoals, Alabama. He also visited the USDA laboratories at Beltsville, Maryland, and the Agronomy Department of Iowa State University at Ames. Dr D. Vaughan attended the 10th International Congress of Biochemistry, held in Hamburg. Dr H. A. Anderson visited the Institute for Soil Fertility, Haren, The Netherlands; the Federal Agricultural Research Station, Braunschweig, West Germany; and the Soil Survey Department of the University of Ghent. Visits were made by members of staff to meetings of the Chemical Society, the Society for Experimental Biology and the Association of Applied Biologists.

Soil Polysaccharide

Studies on the origin of soil polysaccharide have continued in collaboration with the Department of Microbiology.

It has previously been shown[43] that incubation temperature can influence the composition of polysaccharide synthesised in soil after the addition of ^{14}C glucose substrate. At 5°C the content of xylose is much higher than at 20°C, probably due in part to a greater contribution from yeasts, and is more in keeping with the content in the native soil polysaccharide. At neither temperature, however, is the arabinose content as high as in the native material. The effect of varying other factors, including light, pH over the range 4·0 to 7·5, and degree of aeration, has now been examined. Little synthesis of arabinose has been obtained under these conditions, supporting the suggestion that the pentose fraction of the soil polysaccharide is mainly derived from the undecomposed residues of plants.

305, 506, 5613

The rate of decomposition of the polysaccharide in plant tissue is being assessed using plants grown in soil in an atmosphere containing $^{14}CO_2$.

Preliminary results indicate that the persistence of the plant pentosans is considerable. Very little ^{14}C appears to be taken up by a fallow soil under $^{14}CO_2$. 305, 506, 5613

An hypothesis that soil polysaccharide is synthesised by free enzymes in soil has been explored by incubating soil, sterilised either by autoclaving or γ-irradiation, with ^{14}C glucose. Insignificant amounts of glucose were transformed to other sugars after 28 days and most of the glucose could be extracted by 80 per cent ethanol showing that it was not present as polysaccharide. 305, 506, 5613

Papers describing an automated method of sugar analysis using *p*-hydroxybenzoic acid hydrazide[44] and on the chromatographic determination of uronic acids in soils[45] have now been published. Reviews dealing with polysaccharide in soil[105] and its origins and stability[106] have been accepted for publication.

Chemical Taxonomy of Podzolic Soils

Investigations on the organic matter in podzols, mentioned in previous reports, have continued. In collaboration with the Department of Soil Survey, samples from podzolised soil profiles under natural or semi-natural vegetation have been examined.

Standard analyses had previously been carried out in the Department of Pedology and, in addition, samples have now been analysed for forms of inorganic phosphate and acid-extractable iron, aluminium and organic matter. Approximately 2000 samples from 220 profiles were examined and the results should lead to a better understanding of the genesis of such soils. 304, 804

Soil Organic Nitrogen, Sulphur and Phosphorus

Further studies have been carried out on the composition of the amino acids in a variety of soils and soil organic fractions and, in collaboration with the Department of Soil Fertility, sulphur-containing amino acids are being studied. Two joint papers describing organic sulphur fractions in Scottish soils[46, 47] have now appeared. 303, 602

A biochemical investigation into the effects of soil organic matter on the breakdown of organic phosphates has been initiated. Because of some conflicting reports in the literature concerning the activity of both soil and plant phosphatases, the reaction kinetics of an acid phosphatase from wheat roots have been studied in some detail, using *p*-nitrophenyl orthophosphate as a substrate. This phosphatase has an optimal pH of 4·5 and K_m of $5{\cdot}4 \times 10^{-4}$M. The acid phosphatase activity of wheat roots, grown for up to 14 days under axenic conditions, is inhibited by humic and fulvic acids, and by material extracted from soil with hot or cold water, but not by soil polysaccharides. 311, 317

Metal Complexes of Humic Substances

The study of metal complexes of soil organic matter has continued in collaboration with the Department of Spectrochemistry. Papers on the nature of the bonding of vanadium with humic acid[41], on the occurrence

of copper porphyrin complexes in humic acids[42] and on the composition of soil humus[40] have now been published. The effect of pH on the form of iron in suspensions of humic acid is being examined using Mössbauer spectroscopy. 203, 307

Comparison of Synthetic and Natural Humic Substances

As noted in Annual Report No. 45, 1974-75, a high proportion of the humus in podzol B_h horizons occurs as acid-extractable aliphatic or alicyclic polycarboxylic acids. It has now been found that these are virtually indistinguishable from the fulvic acid polymers in alkali extracts of arable surface soils in this area and from water-extractable humus from the same soils[107]. The synthetic polycarboxylic acid, polymaleic acid, also bears a very close resemblance to these natural materials, showing similar structural features[57] and physiological activity[108].

Acid hydrolysis of polymaleic acid yields succinic and fumaric acids, also invariably produced by hydrolysis of humic and fulvic acids. Plant and microbial decomposition products such as phenols, amino acids, polypeptides, polysaccharides and lignin can be incorporated into the growing synthetic polymer as covalently bound units, or surface adsorbed on preformed polymaleic acid, giving materials very similar in properties to soil humus. Thus alkali treatment of the initially acid-insoluble portion of the crude product yields both acid soluble ("fulvic acid") and acid insoluble ("humuc acid") fractions. The relationship between solubility and pH for the "humic acids" is similar to that of the natural products and fractionation of the synthetic material by gel chromatography gives polypeptide and polysaccharide distributions similar to those in chromatograms of the natural products. The "fulvic acids" can be fractionated by chromatography on charcoal to yield products similar to those from soil fulvic acids.

Whilst the physiological activities of the synthetic "fulvic acids" and "humic acids" have yet to be investigated, the pure synthetic polymaleic acid has been shown to possess growth promoting properties, assayed by the growth response of cultured tomato roots[48], comparable with the purified polycarboxylic acids of natural fulvic acid and water extractable soil humus. Fractionation of the synthetic polymaleic acid on the basis of molecular size by membrane ultra-filtration has shown that maximum physiological activity occurs in the molecular weight range 500-1000 which is similar to that found in fulvic acid and in the water extractable humus of agricultural soils. The highest molecular weight fractions exhibit similar physiological activity, but of less magnitude, whereas the low molecular weight hydrolysis products of polymaleic acid, succinic and fumaric acids, show growth promoting activity towards cultured tomato roots, which is qualitatively distinct from that of the polymers. 208, 303, 304, 309

Effects of Humic Acid on Plant Growth and Nutrition

Under certain specified conditions, such as iron deficiency or heavy metal toxicity, the growth of wheat plants can be greatly improved by the addition of humic acid or related substances, the beneficial effect being attributable

to the complexing properties of the acid. Attempts have been made to identify other situations in which humic acid gives improved growth, but progress has been slow, partly because of the difficulty of excluding a complexing effect as a contributory factor.

The growth of cereal roots in dilute solutions can sometimes be unaccountably retarded, although this seldom occurs in the presence of humic acid. In an attempt to provide a reproducible environment for the growth of cereal seedlings, disposable sterile polystyrene Petri dishes have been modified to give a convenient and inexpensive growth chamber in which seedlings will grow to the third leaf stage with minimal attention[109].

309

Root growth in wheat seedlings is improved in the presence of humic acid under a range of conditions, although the improvement is sometimes slight. However, one set of conditions has been identified where the addition of humic acid is markedly inhibitory. During a study of the effect of pH on root growth it was found that in a 10mM phosphate buffer solution containing 3 mM $CaCl_2$ the addition of 50 mg/litre humic acid severely limited root growth over a narrow pH range around 6·4. The cause of the inhibition has not yet been positively identified, but it is probably the result of some interaction between the chemical constituents of the solution, none of which by itself is inhibitory at pH 6·4.

A similar effect has been obtained with fulvic acid, but with an upward shift in the pH to 6·6. An inhibitory effect of this kind with humic substances has not previously been reported. 309

Investigations are being carried out on the interaction of humic acid and plant growth regulators. Abscisic acid is inhibitory to the growth of wheat seedlings, but the addition of humic acid has produced effects suggesting that the humic acid partially alleviates the inhibition of root elongation, but not the inhibition of shoot growth. In contrast, addition of the synthetic cytokinin, 6-benzyladenine, to the external solution alleviates the abscisic acid inhibition of the shoot but offers no protection to the root. Humic acid also causes some improvement in the germination of lettuce seeds treated with abscisic acid but much less than the well-documented effect of kinetin with abscisic acid. 309

Papers describing investigations on the growth of wheat plants in ^{14}C-labelled humic acid solutions under axenic conditions[49] and on the differential effects of humic acid on the absorption of cations by beet disks[50] have now been published. A study of the effects of humic and fulvic acids on the stimulation of peroxidase activity in beetroot disks during ageing, mentioned in Annual Report No. 43, 1972/73, has now been completed and a report is being prepared for publication. 309, 311

Water Extractable Organic Matter

It has now been established that readily soluble organic components, extracted from a number of soils with cold water, enhance the growth of wheat roots by about 10 per cent when these are grown in full nutrient solution under axenic conditions. Some of the activity is likely to be associated with humic substances (see above) but other physiologically

active components, of lower molecular weight, are also present and a number of these are being studied in some detail. The water extracts contain several phenolic acids, principally *p*-hydroxybenzoic, vanillic, *p*-coumaric and ferulic acids, with smaller amounts of 3, 4-dihydroxybenzoic, *m*-hydroxybenzoic and syringic acids.

Tests with the four phenolic acids present in largest amount showed that they stimulated the growth of wheat roots in full nutrient solution and of excised pea root segments in sucrose solution. Fumaric and succinic acids, also found in the water extracts, did not affect the elongation of excised pea root segments. 311

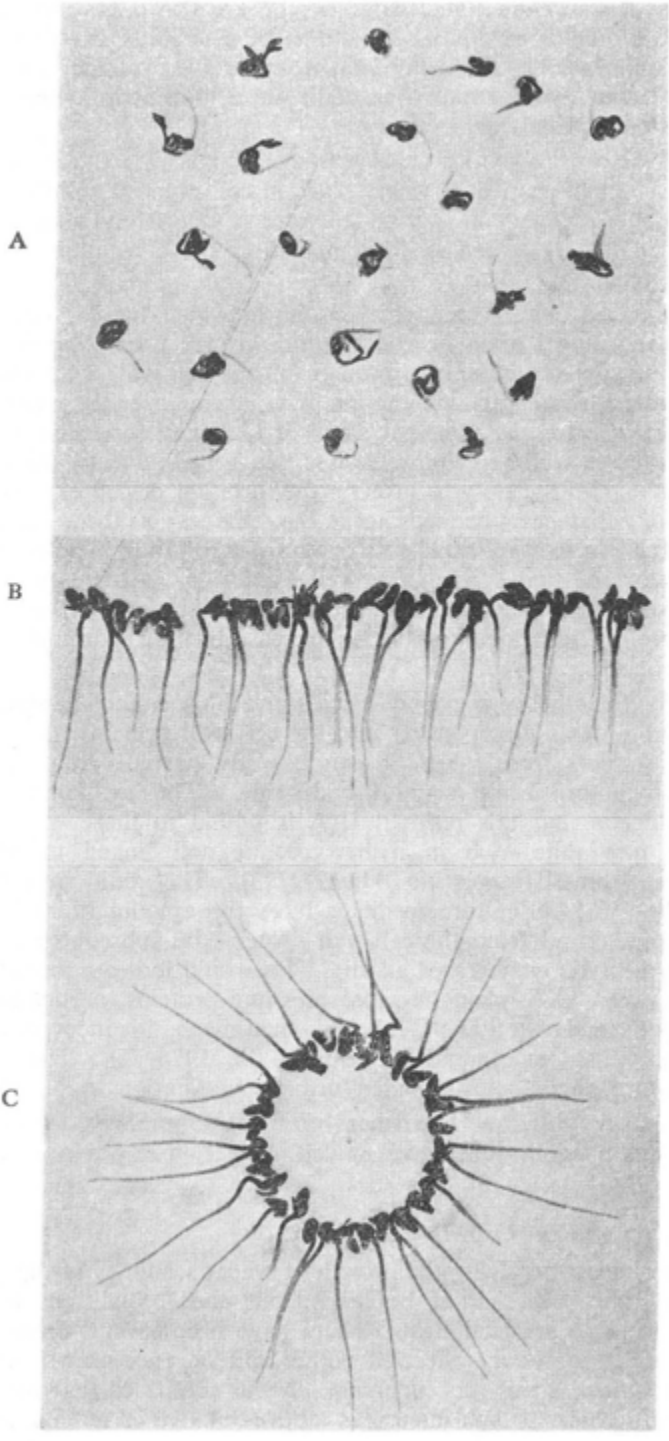
Experiments have also been carried out in which indole-3-acetic acid (IAA) and the fungal toxin fusicoccin (both growth promoting substances bringing about the excretion of protons from the cell walls of some higher plants) have been used in conjunction with phenolic acids. The results indicate that whereas the principal effect of IAA and fusicoccin is on the growth rate of expanding cells in excised pea root segments, the effect of the phenolic acids is mainly to prolong the duration of cell expansion. It seems unlikely that phenolic acids act in the same way as those growth substances which can cause a rapid loss of protons, resulting in a loosening of the cell walls and hence promoting cell expansion. At present it seems more plausible that phenolic substances delay in some way the processes that are involved in bringing about an increase in the rigidity of the walls of expanding cells.

But interactions between phenolic acids and IAA cannot be discounted. ^{14}C-Labelled IAA is incorporated into the cell-wall proteins of elongating pea root segments from which it can be only partially removed using pronase, chymotrypsin or sodium hydroxide. The available evidence strongly suggests that this residual IAA is bound to those wall proteins which are non-labile, rich in hydroxyproline and linked to arabinose residues (see Annual Report No. 43, 1972/73). The addition of phenolic acids to the ^{14}C-IAA culture media reduces the amount of radioactivity that can be removed from the cell-wall proteins by subsequent treatment with the proteolytic enzymes or alkali. This would indicate that there are linkages between IAA, phenolic substances and proteins, particularly as it has already been shown that ^{14}C-labelled cinnamic acid is incorporated into cell-wall proteins (see Annual Report No. 45, 1974/75). The mode of action of soil phenolic acids is under further investigation. 311, 402

A joint paper with the Department of Plant Physiology describing the effect of some phenolic substances on cell elongation in pea roots has now appeared[51]. 311, 402

Effect of Light on Root Growth

The experiments involving the growth of wheat seedlings in the presence of organic components had to be carried out under conditions which exposed the roots to artificial light. There have been several reports in the literature of an inhibitory effect of white light on root growth so it was necessary to check if this was occurring. It was confirmed that wheat roots are sensitive to light at high intensities (above $3{:}4 \times 10^3$cd m^{-2} i.e. 1000 foot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candles) but not at the intensities to which they are usually exposed under routine laboratory conditions. A number of plants were examined for light sensitivity of their roots, including cress which is one of the most sensitive species. It was found that the light sensitivity of the cress root was manifested only on the horizontal plane, vertically growing roots being unaffected by light. The light inhibition of root elongation was shown to be a function of the plane of growth and to be reversible. Subjecting the roots to a force field on the horizontal plane prevented the inhibition. A preliminary report on the interaction of light and gravity on the elongation of cress roots has been published[52]. 309

Blossom-End-Rot in Tomatoes

A collaborative investigation with the Department of Plant Physiology into the metabolic changes occurring in tomato fruits developing blossom-end-rot has shown that the affected tissues have much higher levels of invertase, peroxidase and phenolase activities than do comparable areas of unaffected fruits. The total reducing sugar contents of the affected areas are, however, lower. The phenolic material, which might be responsible for the darkening in the affected tissues, increases threefold and there is also a 50 per cent increase in the protein content of these areas. These investigations are continuing. 311, 402

Left—The effects of force field on the growth of cress seedling roots.
Seeds were imbibed for 16 hours and the germinated seeds then allowed to grow for a further 24 hours at 27°C while exposed to a light intensity of 600 foot-candles (*c.* 2000 cd m^{-2}). A: Seedlings grown in a horizontal plane showing retarded root growth in the presence of light. B: Seedlings grown in a vertical plane showing the improved root growth due to the effect of gravity. C: Seedlings grown horizontally in a dish rotating at 400 rpm with the roots subjected to a centrifugal force of *c.* 9 g.

4. PLANT PHYSIOLOGY

Dr P. C. DeKock

Work has progressed steadily throughout the year, emphasis being largely on the metabolism of calcium in the plant. It is gratifying to know that partly as a result of this work blossom-end-rot of tomatoes can be largely eliminated from glasshouse culture in Scotland.

Dr DeKock presented a paper at the Scottish Electron Microscopy Conference in Edinburgh during April. In July, Dr A. E. S. Macklon attended the International Workshop, on Transmembrane Ionic Exchanges in Plants, held in Rouen and Paris, under the auspices of the Centre National de la Recherche Scientifique.

Calcium

It has become apparent during the past few years that the induction of calcium deficiency symptoms in glasshouse tomatoes may be related to the presence of appreciable levels of ammonium ion in the substrate and that severe calcium deficiency may be induced in varieties susceptible to the disorder by use of nitrogen fertilizers containing the ammonium ion, whereas it can be almost entirely eliminated with the use of nitrate fertilizers provided of course that the calcium status of the soil is adequate. The physiological basis of this disorder had been worked out in this department as early as 1952 when it was shown that the ammonium ion causes an imbalance of organic and inorganic ions. This viewpoint has now been fully explored in most of its implications. It has been shown that urea has a similar but smaller effect on calcium nutrition probably because there are alternative pathways of metabolism.

As calcium deficiency can now be induced at will, detailed studies on the disorder in tomatoes have been made. It has been shown that in affected tomatoes the enzymes peroxidase and invertase are greatly increased in activity compared with healthy ones. Also, as was found for calcium deficient potato sprouts[53], total phenols, chlorogenic acid and caffeic acid are higher in affected tissues.

Tissues of affected tomatoes have been shown to fluoresce very strongly when illuminated with UV light under the microscope whereas healthy tissue hardly fluoresces at all. Fluorescence in plant tissues is often due to a high phenolic content. In contrast to potato, our studies on the activity of phenylalanine ammonia lyase activity have been unrewarding in tomato.

Cavity spot in carrots is another disorder attributed to calcium deficiency. By growing carrots in pots of sand it has been possible to induce cavity spot in the presence of ammonium salts whereas carrots grown with nitrate fertilizers under otherwise identical conditions were largely free of the disorder. Investigations are proceeding. 402

Following the appearance of reports in the literature that the nitrate ion may be reduced to ammonium in soils which are exposed to drying and rewetting, joint studies have been initiated with the Peat and Forest Soils

Section of the Department of Pedology to investigate how readily the ammonium ion is generated from added nitrate in the peat substrates in which tomatoes are grown commercially. If, in fact, the ammonium ion arises under these conditions it would adequately explain one mechanism by which calcium deficiency is said to be induced by an irregular water regime. 114

Tomato plants have been grown in nutrient culture to which varying amounts of EDTA were added, as it had been shown that this chelant could produce calcium deficiency in *Lemna*. The effects of EDTA, in this instance, are rather drastic, reducing the available amount of most cations and also reducing the percentage total nitrogen in the plant. 402

Active Iron

Studies on active iron in maize leaves have shown that this fraction of iron is not closely related to the total iron, but rather to the ratio of total phosphorus to total iron. The effect of soil moisture on availability of iron and phosphorus generally means that both become more easily available to the plant. However, absorption of both elements takes place so as to minimize the effects of an adverse environment and to keep the active iron fraction fairly constant. 401

Peroxidase

Studies on polarity in the potato tuber have been made over the past winter and two papers have been accepted for publication[110, 111]. The newly matured tuber shows little polarity in the distribution of peroxidase, but this becomes progressively more apparent and is finally much greater at the rose (sprout) end than at the heel (stem) end. 401, 311

Aluminium

Research on aluminium toxicity has progressed. In lucerne leaves there is an apparent relationship between total phenols and aluminium content. Further analyses have been carried out on affected lucerne and brome grass and the results are being assessed statistically. Studies on plants which can tolerate relatively large amounts of aluminium in their tissue apparently show an enhanced citric acid content, as has previously been observed in tolerant grasses. 401

Ion Flux Studies

In Annual Report Nos. 40 and 41, reference was made to flux studies using beetroot storage tissue disks. When beet disks are freshly cut, the net accumulation of ions is very small compared with its subsequent development. Experiments were undertaken to determine whether this is due as much to high initial ion efflux as to the initial absence of an absorption capacity. Beetroot were grown in nutrient solutions containing high specific activities of ^{22}Na or ^{36}Cl, so that tracer efflux could be followed directly after slicing the beet, and compared with efflux measurements on disks loaded with isotope by incubation in labelled solutions after slicing. Using compartmental flux analysis, a procedure described in earlier reports, it has

now been demonstrated that, in accord with the generally accepted view, net Na^+ influx follows from a reduction in efflux with ageing, and net Cl^- uptake depends on a marked increase in influx. However, contrary to earlier beliefs, both these important changes were found to occur at the inner cell membrane (tonoplast) and although ageing led to a reduction of plasmalemma fluxes, at no time was entry to Cl^- into the cytoplasm, or loss of Na^+ from the cytoplasm, significantly restricted. An account[54] of this work has now been published. 407

Flux studies, using the well characterized onion root segment system, continue. Examination of Ca^{2+} fluxes is being extended to include the effects of varying external Ca^{2+} concentration, EDTA amendments and heavy metal toxicities. A paper[55] reporting the nature of Mg^{2+} fluxes in onion root segments has now appeared. 407

An account of further work on membrane permeability and related physiology in yam tubers, in collaboration with the School of Agriculture, Aberdeen, has now been published[56]. 407

A paper[57] describing the energy pathways involved in Cl^- uptake in wheat leaf tissue has now appeared, and further experiments are in progress. 407

Calcium Uptake and Transport in Tomato Plants

In conjunction with glasshouse experiments in which tomato plants have been grown in various peat-based substrates, and from which correlations have been obtained between the incidence of blossom-end-rot and the type of nitrogen nutrition, a parallel study has been undertaken, using plants grown in water culture, to examine specifically the relationship between nitrogen source and Ca^{2+} absorption and transport within the plant. Uptake and transport in the short term are estimated by detopping the plants and collecting the exuding xylem sap for analysis. Long term estimates are made from analyses of the various plant parts (stem, leaf, root) at the end of a ten week growing period. Earlier work in this department has amply demonstrated that the Ca^{2+} content is depressed in plants whose nitrogen source is mainly or exclusively from ammonium salts. The present work aims to measure the extent to which this effect is due to alterations in uptake and transport mechanisms. 402, 407

5. MICROBIOLOGY

DR J. F. DARBYSHIRE

The principal aims of the research programme in the Department of Microbiology are to assess the significance of soil microbes in the decomposition of organic matter and in microbial interactions with plant roots. These broad objectives are included within research package 5 and necessitate close collaboration with other departments of the Institute and with allied research centres as mentioned below.

Two long-serving members of the department, Dr D. M. Webley and Miss I. F. Taylor, left the Institute during the year. Dr Webley retired at the end of January 1976 after more than 30 years at the Institute and as head of the Department of Microbiology since 1959. Under his leadership, 85 scientific papers have been published dealing with either soil actinomycetes, bacteria, fungi or protozoa. Miss Taylor resigned at the end of August after 30 years of devoted service. Dr J. L. Neal returned to the Canadian Department of Agriculture Research Station at Lethbridge, Alberta, after one year in the department. Dr G. P. Sparling was appointed to the staff in November 1975 and Miss R. M. West, research student sponsored by the A.R.C., commenced a study of the microbial decomposition of plant roots in September 1976.

During the year, six members of staff attended scientific meetings or instructional courses: Dr J. F. Darbyshire—VI International Colloquium on Soil Zoology (I.S.Z.) in Uppsala, Sweden; Dr J. F. Darbyshire and Mrs C. M. Macdonald—Joint Meeting of the British Section of the Society of Protozoologists (B.S.S.P.) and British Phycological Society (B.P.S.) in Glasgow; Dr D. Jones—A.R.S. Conference on Electron Microscopy in Edinburgh and the Micro-76 International Symposia and Exhibition organised by the Royal Microscopial Society (R.M.S.) in London; Dr G. P. Sparling—A.R.S. "Quantimet" Users' Meeting in Harpenden and the Joint Meeting of the Association of Applied Biologists (A.A.B.), British Mycological Society (B.M.S.) and Federation of British Plant Pathologists (F.B.P.P.) in Edinburgh; Mr R. E. Wheatley—Summer Conference of the Society for Applied Bacteriology (S.A.B.) in Lancaster; and Mr M. S. Davidson—Principles of Light Microscopy organised by R.M.S. at Uxbridge. Joint papers were read at the following: the I.S.Z. colloquium, the B.S.S.P./B.P.S. meeting and the A.A.B./B.M.S./F.B.P.P. meeting. In collaboration with Mr D. Watson of the Agricultural Botany division, North of Scotland College of Agriculture, an exhibit of electron micrographs by Dr Jones were displayed at a symposium on syllabuses and course content for crop protection courses organised by the British Crop Protection Council at Stirling. A standard 8mm cine colour film belonging to Dr Jones and dealing with field and laboratory observations on the fungus, *Sclerotinia sclerotiorum*, was shown by Dr P. J. Shipton of the Plant Pathology division, North of Scotland College of Agriculture, at an A.D.A.S. open conference of advisory plant pathologists at Northampton.

Interrelationships of Plant Roots and Microbes

The results of the study of the microbial populations and nitrogen status of the rhizosphere soil around the roots of spring barley, grown in Kincardineshire fields were reported in a joint paper with the Department of Soil Fertility and the Plant Pathology division, North of Scotland College of Agriculture[112]. Regular bioassays of the soil in the fields after harvest of the barley crops showed an increase in the incidence of *Gaeumannomyces graminis*, the fungus causing take-all disease, until mid-winter and then a sharp decline to low levels in early spring. Microbial antagonists to *G. graminis* near the roots, which remained in the soil after harvest, also reached their maximum in mid-winter. Fluorescent bacteria, isolated from a selective medium for pseudomonads, were the predominant antagonists to *G. graminis* during the first three months after harvest in 1974 but were not detected after harvest in 1975. The largest increases in take-all disease in barley crops occurred during the period when the ratio of NH_4^+ N:NO_3^- N in the rhizosphere increased considerably. Experiments in the glasshouse with sieved soil from the same fields and with different levels of either aqueous ammonia with the nitrification inhibitor " N-serve " or potassium nitrate added to the soil showed that within the first two months after germination of the barley the largest incidence of take-all occurred in those treatments with high $NH_4:NO_3$ ratios, i.e. in those treatments with aqueous ammonia rather than potassium nitrate. A further experiment is in progress in the glasshouse to confirm these results using greater replication, an additional method of disease assessment and nitrogen fertilisers applied as foliar sprays. 504, 603

Existing techniques for growing axenic plants have been simplified. In collaboration with the Department of Soil Organic Chemistry, ^{14}C-labelled barley plants have been produced with these techniques. This labelled plant material will be used in studies concerned with the decomposition of organic matter . 305, 504, 506

Improved methods for examining microbes in soil and root surfaces have been developed, utilising incident UV light microscopy and fluorescence brighteners. 504, 506

In collaboration with Dr Neal, visiting research worker from Canada, an electron microscope study has been made of a nitrogen-fixing bacterium which was previously isolated by Dr Neal from the roots of a selected line of Canadian wheat. In monoxenic culture with this Canadian wheat, the bacterium was found in the intracellular spaces between the cortical cells of the root as well as in the mucilaginous layer on the root surface. The significance of such microbial colonisation in terms of the growth of cereals requires further investigation. 504

Fungi

Ultrastructure. A paper describing the ultrastructure and chemical composition of spines in Mucorales has been published[5]. 109, 507

There have been several investigations on the organic components of cell walls of fungi, but few on the inorganic elements. The feasibility of using the electron probe microanalyser attachment of the scanning electron

microscope to analyse cell walls has been examined and a paper incorporating the results has been accepted for publication[76].

Phosphorus, sulphur, calcium, chlorine and magnesium were positively identified in isolated hyphal and spore walls of *Cunninghamella echinulata* and their presence was confirmed by chemical and spectrochemical analysis. Fungal walls have been analysed at the A.E.I. laboratories in Manchester by an instrument which provides full transmission electron microscope facilities and in addition a solid state detector and analyser for detection of X-rays from chosen areas of the specimen under observation, and two application sheets have been published by them. One describes the distribution of elements in ultra-thin sections of the apothecium of *Sclerotinia sclerotiorum* and the other reports on the qualitative analyses of the elemental composition of the hyphal walls of *Rhizoctonia solani* Kuhn, the causative organism of Black Scurf in potatoes. 109, 507

Sclerotia of Plant Pathogens Visits were made in July and August to six farms in north-east Scotland where nearly 90 ha of vining peas were grown. The object was to assess damage caused by *Sclerotinia sclerotiorum*. There was little evidence of the disease on any of the farms where, in previous years, some crop damage had resulted from the presence of the fungus. The drought, which prevailed during the summer, was undoubtedly unfavourable for growth of the fungus. However, the disease was seen on giant hogweed *(Heracleum mantegazzianum)* at Lonmay, near Peterhead. The effect is rather spectacular since the plant grows to a height of 2·5 to 3·5 m as shown in the accompanying photograph. The fungus was also found nearby in a potato field. 508

A paper describing the fine structure of pea stem lesions, caused by *S. sclerotiorum*, and the manner in which the fungus enters potato leaves has been accepted for publication[113]. 507, 508

Protozoa

Survey of Scottish Soils. A joint paper describing an unusual amoeboflagellate, previously isolated from 19 soils (Annual Report 1974/75), has been accepted for publication[114]. A new genus has been proposed for this amoeba which has also been isolated from freshwater in England and the U.S.A. 510

Systematics of Flagellates. A redescription of the colourless soil flagellate, *Heteromita globosa*, (Annual Report 1974/75) has been accepted for publication[115]. A similar study of *Spiromonas angusta* is being prepared for publication. Unlike *H. globosa*, the latter colourless soil flagellate possesses a buccal cavity and a cytopharynx analagous to those found in *Bodo* spp., but a kinetoplast is absent. 510

Growth in Liquid Media and Soil. A paper dealing with the growth of the ciliate, *Colpoda steini*, and the nitrogen-fixing bacterium *Azotobacter chroococcum* in soil samples, which had either been saturated or subjected to one of a series of pF values for 35 days has been published[58]. (Annual Report 1974/75). The growth of these organisms in liquid nutrient media has also been studied and is the subject of a joint paper submitted for publication[116]. 502, 505

Giant Hogweed, *Heracleum mantegazzianum* Somm. & Lev.
A: Whole Plant.
B: Black sclerotia within the stem.

Organic Matter

Microbial Decomposition and Synthesis. In collaboration with the Department of Soil Organic Chemistry, the microbial synthesis of polysaccharide in soil (Annual Report 1973/74) has been examined under aerobic conditions at 25°C. Further work is in progress using lower temperatures and anaerobic conditions. The isolation of soil microbes capable of synthesising xylose has also continued. Investigations on γ-irradiated soil (5 Mrad)

showed that negligible polysaccharide synthesis occurred in these sterile conditions and such soil samples will be used for studies on carbohydrate transformations by specific soil microbes. 305, 504, 506

Peat. A survey of the aerobic bacteria in a local basin peat at Lyne of Skene has been published[59]. A similar survey of anaerobic microbes in the same peat deposit has been initiated and additional data about the aerobic bacteria have been collected. 116, 503

In collaboration with the Department of Pedology, a study has commenced of the microbes in six peat composts used for horticultural crops. Six successive crops of tomatoes have been grown on these composts and preliminary investigations suggest that large active populations of bacteria and actinomycetes are present. 114, 503

The presence of triterpenoids have been detected in the Lyne of Skene peat deposit in collaboration with the Organic Geochemistry unit, University of Bristol. The largest quantities of these triterpenoids were present in the peat immediately beneath the living *Sphagnum* and cotton grass and they have been detected also in large batch cultures of aerobic bacteria isolated from the same region of the peat. Other organisms in the peat, e.g. algae and moss, will also be analysed for the presence of these compounds. 502, 503

Microbial By-Products

In collaboration with the Department of Bacteriology, St Mary's Hospital Medical School, London, and the Department of Spectrochemistry of this Institute, a study of the chelating effect of 2-keto gluconic acid on human renal stones has been initiated. Preliminary results suggest that appreciable amounts of calcium can be released from these stones by this bacterial chelating agent. 502

6. SOIL FERTILITY

Dr E. G. Williams

As well as research on various aspects of soil-nutrient-crop relationships, the department's responsibilities continue to include extensive consultative activities. The principal objective remains the improvement of manurial practices, soil fertility and crop production.

Investigations have been continued and extended (1) on the nutrient relationships, properties and productivity of contrasting soil series mapped by the Soil Survey of Scotland, (2) on the effects of fertilizers, soil conditions, husbandry practices and environmental factors on the growth, development and chemical composition of crops, and (3) on the development, calibration and practical application of laboratory methods for assessing the lime and nutrient status of soils for advisory purposes. The overall experimental approach continues to be concurrent development and integration of complementary field, pot culture and laboratory studies, with the emphasis on the behaviour of the soil as a whole and on the main agricultural crops. This approach is designed to identify and quantify the various soil properties and processes which regulate nutrient supply and crop growth, and which underlie influences of pedological factors, particularly effects of soil parent material and drainage status. It also provides practical information about the performance and fertilizer requirements of the different soils and crops.

The main research topics are briefly reviewed below, and during the year there have been three new appointments. Two of these are concerned with the application of recent advances in electrochemical techniques, particularly ion selective electrodes, cathodic and anodic stripping voltammetry and differential pulse polarography, to study nutrient relationships in soils. Among the applications envisaged are (a) direct measurements of nutrients in moist soil, (b) differentiation of ionic species in soil and plant extracts, (c) *in situ* monitoring of the pattern of nutrient supply in the field, and (d) miniaturization of equipment to examine soil heterogenity and the root-soil interface. Dr G. P. Bound has joined the staff to develop studies in these areas, with particular reference to the composition of the soil solution and to soil nitrogen relationships, and Dr T. E. Edmonds has been appointed as from January 1977 to study the kinetics of desorption and transport processes for different nutrients, including heavy metal ions, in soils. These studies can be regarded as logical extensions of investigations during the first half of this century employing the relatively simple techniques then available, especially electrodialysis, which contributed much to basic understanding of soil properties and processes.

The third new appointment concerns the influences of soil physical properties and conditions on crop production on different soil series. Dr G. D. Buchan has been appointed to develop studies in this field.

Attention continues to be given to practical questions and to translation of research findings into practice. In these respects, the consultative activities, especially advisory soil testing in collaboration with the North of

Scotland College of Agriculture, are particularly valuable. So also are associated contributions to various agricultural meetings and representation on technical committees. The latter are mainly under the auspices of the Department of Agriculture and Fisheries for Scotland and currently include: the Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs; the Consultative Committee for the Development of Spectrochemical Work; the Scottish Farm Waste Committee; the Working Group on the Disposal of Sewage Sludge on Agricultural Land; and a Study Group considering the Report of the Working Party on Land Use Capability Classification. The department was also represented at meetings of the British Society of Soil Science, at a conference of Scottish Grassland Workers, and at a discussion on Agricultural Practice Surveys organized by the Scottish Agricultural Development Council.

With the assistance of the three Scottish Colleges of Agriculture, a paper on lime and crop production in Scotland was prepared for the Soil Science Committee of the Arable Crops and Forage Board of the Joint Consultative Organization for Research and Development in Agriculture and Food. The main features are summarized later.

Dr J. W. S. Reith visited the Centre National de Recherches Agronomiques, Versailles, France, and attended an International Conference on Very Long-Term Fertilizer Experiments and Their Results, at the Institut National Agronomique, Centre de Grignon, in July. Dr Reith also attended a Conference on the Improvement of Marginal Land, organized by the North East Scotland Development Authority in Aberlour, in May, where he contributed a paper on the technical aspects of the subject. Dr W. M. Crooke attended the Summer Residential Meeting of the Association of Applied Biologists, held in the University of Edinburgh, in July. At the invitation of the Agricultural Isotopic Commission of the Polish Academy of Sciences, Mr A. H. Knight attended the VIIth Annual Meeting of the European Society for Nuclear Methods in Agriculture, in Warsaw, in September.

During a stay of seven months in the Institute, with the aid of an F.A.O. award, Mr A. M. Abbass, Soil Survey Administration, Sudan, spent the major part of his time in the Department of Soil Fertility, gaining experience of methods of chemical soil analyses.

Crop Responses to Fertilizers

A major objective of the field experiment programme continues to be extension of information on the nutrient status and productivity of different soil series, on the fertilizer requirements, yields and mineral composition of the main agricultural crops, and on the calibration of advisory soil testing methods. As indicated below, there is also continuing need for up-dating information on forms, methods and times of application of fertilizers.

601, 603, 608, 5206, 5701, 5703

Comparison of Solid and Liquid Fertilizers on Barley In recent years there has been an appreciable increase in the use of liquid fertilizers. Differences in the chemical composition of these compared with standard granular products, particularly the presence of urea, may influence their effectiveness,

especially when combine drilled. Another factor to be taken into account is the substantially higher optimum nitrogen requirements of the newer barley varieties. Consequently, one of the NPK fertilizers currently in extensive use has a $N:P_2O_5:K_2O$ ratio of 2:1:1. In 1975, therefore, three barley experiments were carried out to compare granular and liquid forms with this nutrient ratio, when broadcast, combine drilled with the seed, and placed 5 cm to the side of the seed, at rates up to 100 kg N per ha. Probably due to the moist soil conditions produced by over 90 mm of rainfall during the six weeks after sowing, there was no evidence of any injurious salt effect from combine drilling. Irrespective of the method of application, the two forms gave similar yields. Placement 5 cm to the side of the seed was at least as good as combine drilling which, as expected, tended to be slightly better than broadcasting. The results are being processed from three similar experiments in 1976. 608, 5701, 5703

Time of Application of Nitrogen for Barley. Earlier work, about 15 years ago, showed no clear or consistent differences between seed-time and later dressings of nitrogen at rates up to 66 kg N per ha as ammonium nitrate in the form of "Nitro-chalk." Since substantially higher rates of nitrogen are now required and fertilizers currently contain more nitrate nitrogen, which is liable to losses by leaching, further tests were considered desirable. At three sites in 1975, dressings of 60 and 90 kg N per ha were broadcast at seed-time and shortly after brairding, when the barley plants were at the two to three leaf stage. Despite over 90 mm of rainfall in the intervening six to eight weeks, yields from the seed-time dressings were just as good as from the later applications, indicating that there had been no significant leaching of nitrate beyond the rooting depth. Three similar experiments have been carried out in 1976. 603, 608, 5701, 5703

Effects of Minimum Cultivation Methods for Barley. In recent years techniques have been introduced, mainly in England, to grow crops, especially barley, without ploughing, or with minimum cultivations, using herbicides to control weeds. Under Scottish conditions, the effects of these techniques on the response to phosphate has to be considered. An experiment was, therefore, started in 1975 to investigate over a number of years the effects of three cultivation techniques, normal ploughing, chisel ploughing and no ploughing, on the effects of superphosphate applied broadcast or combine drilled with the seed. Because of rather deep sowing followed by abnormally high rainfall, the results for the first year were not representative but there was no sign of any major effect of the type of cultivation on either yield or response to phosphate. The indications are, however, that grass weeds, especially couch *(Agropyron repens)*, are less prevalent with normal ploughing. The phosphorus treatments appear to have had a greater effect in the second than in the first year 608, 5701, 5703

Placement for Swedish Turnips. As mentioned in last year's report, investigations are being carried out to check whether findings obtained over 20 years ago using fertilizers based on ammonium sulphate and superphosphate are applicable to current products. In two experiments in 1975 fertilizers were broadcast and placed in a narrow band 5 cm directly below the

seed. Ammonium nitrate as "Nitram" placed at rates supplying 50, 100 and 150 kg N per ha produced practically the same yields as equivalent broadcast dressings. In two other experiments a granular fertilizer with an $N:P_2O_5:K_2O$ ratio of 1:1:1 was placed at rates supplying 25, 37.5 and 50 kg P per ha and compared with broadcast dressings of a normal turnip fertilizer with a ratio of 1:2:1 supplying 50, 75 and 100 kg P per ha. This ensured that the corresponding treatments of the two fertilizers supplied practically the same amounts of nitrogen and potassium. The placed treatments, on the other hand, supplied only half as much phosphate at the broadcast dressings, in the expectation from the earlier work that the effectiveness would be at least doubled by the placement. In fact, at both centres, the placed fertilizer tended to give slightly higher yields than the broadcast treatments supplying twice as much phosphate. As in earlier work the superiority of placement was greater on a soil of the Insch series, which has a relatively high phosphate fixation capacity, than on a soil of the Countesswells series, which has only a moderate capacity in this respect. These preliminary results suggest that current fertilizers based on ammonium phosphate and ammonium nitrate can be more safely placed than the older mixtures based on ammonium sulphate and ordinary superphosphate. Further experiments with the same range of treatments are in progress. 603, 608, 5701, 5703

Phosphate and Potassium Requirements of Grass. With increasing intensity of production, more exact information has become necessary in relation to animal nutrition on the amounts of phosphate required at different levels of applied nitrogen to maintain a level of at least 0·3 per cent P in the dry-matter. An experiment was started in 1973 and continued during three seasons to assess phosphate and potassium requirements at nitrogen rates of 0, 95 and 190 kg per ha per cut, three cuts being taken each year. During the first two years, the maximum yields from the three nitrogen levels were usually obtained with phosphate dressings of 30, 50 and 70 kg P per ha per year, respectively. In the third year, however, double these amounts was necessary; the full yields at the three nitrogen levels were 8.6, 12.6 and 15.6 tonnes dry matter per ha, respectively, and when the respective phosphate dressings were halved to 15, 25 and 35 kg P, the yield in each case was about one tonne less. With potassium, the full yields at the three nitrogen levels were for practical purposes attained with the moderate rates of 30, 60 and 110 kg K per ha per cut, respectively. Higher rates of 45, 80 and 150 kg K produced virtually no increase, while lower rates of 15, 40 and 70 kg were only slightly inferior. The content of both nutrients in the herbage, especially potassium, increased with increasing rate of application and the detailed relationships are being examined with the view to defining more exact requirements. 603, 608, 5206, 5701, 5703

Crop Growth and Development

Detailed studies on the effects of fertilizers, environmental factors and husbandry practices on the progressive accumulation of dry matter and nutrients by barley and swedes or potatoes have been continued at four contrasting field centres. As indicated in previous reports, an important fundamental conclusion is that the yield of barley is more closely related to

growth before, rather than after, ear emergence. This is in contrast to the widely held view that photosynthesis after ear emergence is the major determinant of yield. It is generally accepted that grain number per unit area (the product of ear number per unit area and grain number per ear) is determined by, or before, ear emergence. This implies that grain size is determined by photosynthesis after ear emergence. The results, however, suggest that grain size is closely related to grain number per ear and that this factor is determined, at least partly, by growth before ear emergence. An account of the evidence for these conclusions has been submitted for publication[117]. One implication of the results is that the supply of carbohydrate during the grain filling period is always sufficient to satisfy the storage capacity of the grains. The current net photosynthesis during the filling period, however, is frequently insufficient to account for the rate of carbohydrate accumulation in the grain. In that situation, therefore, it appears that the carbohydrate stored in the straw is utilised to augment the inadequate current photosynthesis. This process is most important in the second half of the grain filling period when, on average, more than 70 per cent of the dry weight increase in the grain can be accounted for by transfer from the straw. This implies that the straw is capable of temporary storage of large quantities of starch or sugars, or both, thereby providing a vital reserve to buffer any effects of adverse conditions on photosynthesis. An account of the quantitative aspects of this mechanism is being prepared for publication, but further work is necessary to study the qualitative changes in the carbohydrate status of barley straw.

Lime and Crop Production

As mentioned in the introduction, a paper on Liming and Crop Production in Scotland was prepared for the Soil Science Committee of the Arable Crops and Forage Board of the Joint Consultative Organization for Research and Development in Agriculture and Food. 604, 608, 610

Soil pH and Crop Yields. Over the past 30 years numerous field experiments have measured the effects of applying lime to raise the pH of mineral soils to about 6·2. A good relationship has been found between soil pH and yields of barley grain in the unlimed control plots, expressed as percentages of the yields produced with adequate liming to about pH 6·2, the R^2 value in the quadratic function being 0·75. The corresponding relationship for herbage in temporary leys was not so good, the R^2 value being 0·57. For both crops the maximum points on the quadratic functions were at pH 6·1. 608

Estimation of Maintenance Requirements. The North of Scotland College of Agriculture, with advice from the Department of Soil Fertility, maintains a series of plots with a range of soil pH values on a light loam of the Countesswells series at their experimental farm at Craibstone, where the average rainfall is about 840 mm and the average annual amount of drainage water about 280 mm. Based on annual assessments over 25 years, the quantities of lime required to maintain soil pH values, measured in 1:2·5 soil:water suspensions, at 5·0, 5·5, 6·0 and 6·5 are 120, 320, 600 and 1000 kg $CaCO_3$ per ha, respectively. 608

Lime Requirements of Scottish Soils. On the basis of advisory soil samples, it appears that the average lime status of Scottish soils has remained fairly constant over the past 10 years. It seems that about 850,000 tonnes $CaCO_3$ would be required annually to maintain the 1,250,000 ha of arable land at pH 6·0 and the 414,000 ha of permanent grass at pH 5·6. If varieties of barley, grasses and legumes capable of providing optimum yields at about pH 5·5 were available, this would reduce the maintenance requirements by about half. The above estimate of annual maintenance requirement does not take account of an initial need for about 5,700,000 tonnes $CaCO_3$ to correct outstanding deficiencies on the arable land and permanent grass, and includes no allowance for the large area of about 5,000,000 ha of rough grazings, most of which are on very acid, lime-deficient soils. If it were possible to improve or adapt the native species, or to breed species, especially legumes, capable of growing satisfactorily on these acid soils, the cost of improving rough grazings would be considerably reduced. 608, 610

Chemical Composition of Crops

Relationships with Yield. The recent emphasis has been on the usefulness of composition parameters at an early stage of growth as indices of final yield of cereals and swedish turnips. An account of work on relationships between the nitrogen and so-called excess base (reflecting organic acids) contents of young barley plants and the final yield of grain has been submitted for publication[118]. For one cultivar in a single experiment with incremental nitrogen dressings, where other growth factors were constant, both parameters at about the six-leaf stage (44 days) gave a correlation of approximately 0·95 with the final grain yield. The time of sampling, however, was critical, especially for excess base, and more extensive field correlations seldom exceeded 0·6. In so far as the final yield with adequate fertilizer varies from one site to another, due to variable influences of other growth factors, exact yield predictions cannot, of course, be expected. Even so, provided reliable minimum values for nitrogen and excess base can be established at the correct stage of growth, both parameters seem capable of giving useful guidance as to whether yield is likely to be limited by inadequate nutrient supply. Their usefulness in this respect, particularly in relation to needs for nitrogen top-dressings, is being further investigated. For example, the effect of plant population, which can vary considerably in practice, has been examined in relation to the rate of change of nitrogen and excess base content with age and to the establishment of suitable limiting values for barley, in a field experiment incorporating five nitrogen levels ranging from 0 to 100 kg per ha N. 606, 607

Nutrient Forms. Crop analyses supporting field experiments normally measure only the total nutrient contents, knowledge of which is essential for interpretation of fertilizer effects and requirements and in relation to animal nutrition. In both respects, it is desirable to examine the forms in which the nutrients are present. Exploratory work has, therefore, been started on selections of crop samples representing different soils and fertilizer treatments, with particular reference to nitrogenous constituents and heavy nitrogen fertilization of grassland. 606, 608

Trace Elements

An account, summarized in last year's report, of experimental work on copper deficient soils during the past 20 years, has now been published[60].

609

Effects of Cobalt, Copper and Zinc on Grass. More information has become necessary on the influences of heavy nitrogen dressings, especially where trace elements have been applied and different soil types are concerned. In a three-year experiment on a mineral soil started in 1973, in which three cuts have been taken each year, the effects of three nitrogen rates of 0, 95 and 190 kg N per ha per cut have been tested in the absence of added trace elements and in the presence of a combined dressing supplying 0·5 kg cobalt, 6 kg copper and 6 kg zinc per ha, all as sulphates, applied early in the spring of 1973. The trace element treatment did not increase yields in 1973 or 1974, but produced 0·6 tonne per ha more dry-matter in 1975. The increase was similar at all three nitrogen rates and was presumably due mainly to the applied copper. A considerable number of samples remain to be analysed, but a preliminary assessment shows, as expected, that application of cobalt substantially increased its content in the herbage. In agreement with previous findings, the corresponding increases for copper and zinc were small. A parallel experiment on reseeded grass on deep peat, is being continued. This tests the effects of treatments applied in 1973, supplying 0·5 kg cobalt, 6 kg copper and 6 kg zinc separately and together, at nitrogen rates of 0, 60 and 120 kg per ha per cut, again with three cuts annually. The trace element applications had practically no effect on yield in 1973 and 1974, but in 1975 the 6 kg per ha copper dressing applied in spring 1973 produced about 1 tonne per ha more dry matter than with no copper added, the increase tending to be marginally greater with 120 kg N per ha per cut than with no nitrogen. Analyses are in progress to examine the effects on the contents of different elements in the herbage. In another experiment, on a copper deficient soil, the relative effectiveness of copper sulphate, copper oxychloride and a commercial copper slag is being tested.

609, 5206, 5701, 5703

Selenium. Animal health problems associated with selenium deficiency are encountered in Scotland. Four preliminary experiments on grassland on contrasting soil series have, therefore, been started to determine, in collaboration with the Department of Spectrochemistry, the effects of small dressings of sodium selenite and sodium selenate on the Se content of the herbage and the soils. 609, 201, 202

Nitrogen

Available Soil Nitrogen. Because of its practical importance, attention continues to be given to the problem of laboratory evaluation of the nitrogen status of soils as a guide to fertilizer requirements. To clarify relationships with different laboratory measurements of soil nitrogen, yield and uptake responses of oats to two nitrogen levels were measured for 20 soils in pot cultures. The plants were also sampled and analysed for nitrogen and ex-

cess base, to follow changes in these parameters and examine their usefulness as indices of final yield and optimum nitrogen requirement. As in corresponding field studies on barley, described earlier, the aim is to define critical minimum values which are necessary at recognizable stages of growth, and to relate these to soil nitrogen measurements and to the nitrogen requirements for optimum yield. In the early stages of growth, little differentiation in nitrogen content due to treatment was apparent, but by the 5-leaf stage, 5 weeks after sowing, only the highest nitrogen treatment which produced the optimum yield had a nitrogen content in excess of 4 per cent. 603, 606

Inorganic Nitrogen in Field Plots. Further information has been obtained on changes in ammonium and nitrate nitrogen during the growth period in field plots with and without added nitrogen, including some measurements of downward movement and preliminary tests on water collected from field drains. As mentioned below in the section on electrochemical techniques, the use of a nitrate selective electrode to facilitate field measurements has been successfully tested. 603

Phosphorus

Determination of Exchangeable Phosphate. Isotopically exchangeable phosphate (E-value), determined with the aid of radioactive ^{32}P in laboratory suspensions, provides a fundamental measure of the quantity of available phosphate in soils. The results, however, can be influenced by several experimental factors and the significance of these is being examined. For a granitic soil of the Countesswells series, the values were not sensitive to variations in the amount of soil or the nature of the suspending salt solution. Rapid shaking of air-dried soils, ground to pass the 0·5 mm sieve, however, gave higher values than from the normal air-dried soil <2 mm, which in turn gave higher values than from field moist soil <3 mm. With the moist soil, an initial rapid exchange was followed by a slow exchange proportional to the logarithm of the time and then by a similar faster reaction, but the distinction between the second and third stages was less clear when dried soil was used with rapid shaking. The effects of rapid shaking and the peculiar kinetics of the exchange with moist soil are, therefore, attributed to exposure of fresh exchange surfaces by breakdown of micro-aggregates. 605

Desorption Isotherms. These define the ability of soils to replenish the solution as phosphate is removed and represent their ability to supply phosphate to plant roots. Studies on differentially enriched soils from field plots, mentioned in last year's report, have, therefore, been continued. Compared with conventional procedures, the presence of even very low concentrations of co-ordinating anions, such as oxalate at 10^{-5}M, in the desorbing electrolyte gives different isotherms. This approach is being studied further with the view to establishing a laboratory method for measuring isotherms compatible with field conditions. 605

A fundamental study of the thermodynamics of anion interaction with soil constituents has also been started. This aims to combine free energy

values determined from exchange isotherms with enthalpy values measured with a microcalorimeter. 605

Evaluation of Soil Phosphate Status. The results from a comprehensive investigation, involving field, pot culture and laboratory studies during several seasons, are being processed to examine quantity-intensity relationships, influences of soil properties, and possibilities of improving laboratory evaluations of the phosphate status of soils for advisory purposes.
601, 608, 610

Sulphur

Status of Soils and Crops. As far as is known, sulphur deficiency is not a factor restricting the yields of crops in North Scotland. As mentioned in last year's report, most of the soils so far examined seem well supplied with available sulphate, but the evidence is limited. A wider examination of the sulphur status of representative agricultural soils, in terms of readily soluble and adsorbed sulphate, has, therefore, been started. Information is also lacking on the sulphur status of crops, which is potentially significant in relation to animal nutrition. Sulphur contents and nitrogen : sulphur ratios of different crops are, therefore, being measured on ranges of field experiment samples representing different soil series and fertilizer treatments.
601, 602, 608

Soil Organic Sulphur. Most of the soil sulphur is, of course, organic and work has continued on the nature of the compounds present, especially the carbon-bonded fraction. In acid mineral soils from North-East Scotland, this fraction accounts for approximately 50 per cent of the total soil sulphur and some of it is present in the form of amino acids. In collaboration with the Department of Soil Organic Chemistry, an assessment is being made of the amounts of sulphur-containing amino acids in a range of soils representing contrasting soil series. Treatment of the soil with performic acid converts methionine and cystine into the more stable methionine sulphone and cysteic acid, respectively. Subsequent hydrolysis of the pre-treated residue with M HCl followed by analysis of the hydrolysate, using an automated amino acid analyser, has indicated that up to 30 per cent of the carbon-bonded sulphur in Scottish soils is present as sulphur-containing amino acids. High levels of iron in the hydrolysate poison the exchange resin and ways of removing iron prior to separation of amino acids are being investigated. 602, 303

Three papers summarized in last year's report have now appeared[61, 46, 67].
601, 602

Potassium and Magnesium

Most Scottish soils contain considerable mineral reserves of potassium and magnesium and the agricultural land has received large amounts of potassium in farmyard manure. The position for both elements, particularly magnesium, has accordingly always been relatively satisfactory, especially compared with the widespread acute deficiencies of lime and phosphate. Due regard has, of course, been paid to the need for adequate potassium dressings, especially for potatoes and intensively used grassland, and to the

magnesium contents of crops in relation to animal nutrition. However, little detailed work has been done on the potassium and magnesium status of different soil types. With increasing intensity of crop production and nutrient removal, it has become desirable to consider the longer-term potassium and magnesium supplying powers of different soils. As indicated in last year's report, detailed studies have, therefore, been started on five contrasting soil series to examine the release of both nutrients from non-exchangeable categories as the exchangeable forms are depleted by continuous cropping with ryegrass in pot cultures. Particular attention is being paid to the significance of differences in clay mineralogy, and adsorption and desorption isotherms in 0·01 M calcium chloride are being used to characterize the quantity-intensity relationships. Crop removals during one year have markedly decreased the exchangeable contents of both nutrients in all the soils. In both cases, however, considerable amounts have been released from non-exchangeable forms and clear differences are emerging between the different soils in this respect. 611

Soil Acidity and Cation Exchange

The work described in recent reports on exchangeable and soluble calcium and aluminium in relation to the pH of acid soils has led to a study of the interrelated soil factors that underlie the effects of acidity on crop growth. A pot culture experiment has been carried out covering the pH range 4·2 to 6·0 (in 0·004 M calcium chloride) for two contrasting soils with different pH-aluminium relationships, using barley and buckwheat as test crops. Large differences in the effects of acidity on growth were evident, depending on both the soil and the crop. Detailed soil and crop analyses are in progress to identify the factors and clarify the relationships involved, especially the role of aluminium and the complicating influences of manganese and phosphate. 604, 606

The development of acidity, associated with the loss of calcium from soils, depends on both the nature of the soil and the composition of the percolating solutions. A detailed laboratory study of these factors has been started in which columns of soil are slowly leached with acid solutions of varying composition. The pH of the effluent is monitored continuously and its composition with respect to other ions is determined periodically. These determinations are being related to changes in exchangeable calcium, magnesium and aluminium in the leached soil. 604

Three papers mentioned in last year's report, two on soil aluminium[62, 63] and one on the measurement of cation exchange capacity of soils[64] have now been published. Invited articles on soil reaction[119], base saturation[120] and activity ratio[121], together with more general contributions on the chemical composition of soils[122] and on the soil solution[123], have been prepared for an Encyclopedia of Soil Science. 604

Electrochemical Techniques

An ion selective electrode has been evaluated for the determination of nitrate ion concentrations in soil pastes. With a non-porous reference electrode, the concentrations indicated by the nitrate selective electrode in

pastes of both field moist and air dried soils correlated well with values obtained by potassium chloride extraction and subsequent colorimetric analysis. Initial trials indicate that direct field measurements of nitrate are feasible. Accounts of these developments have been submitted for publication[124, 125]. An ammonium selective electrode has given reliable results for soil extracts, but serious interference effects have been encountered in soil pastes. 603

Ion selective electrodes are being employed to estimate potassium and calcium + magnesium in soil extracts, and potentiometric and voltammetric techniques for measuring phosphate are being investigated. Preliminary work has been done on water extracts of soils to examine the range of ionic species that can be measured by differential pulse polarography and stripping voltammetry. 601, 604, 609, 611

Initial studies in collaboration with the Department of Spectrochemistry have shown that trace levels of selenium, $<100\mu g/l$ Se, can be measured by differential pulse polarography. 609, 206

Soil Physical Measurements

Measurements of the moisture release characteristics, pore-space relationships and hydraulic conductivity of soil series from different parts of Scotland have been continued. The stoniness of Scottish soils has necessitated some modification of the procedures summarized in the 1973-74 Report (No. 44). Both bulk density and stoniness are now determined on a $10dm^3$ sample in the field, while the upper size limit for fine soil has been increased from 2 mm to 8 mm, to avoid errors in calculating porosity for soils containing gravel in this range. Samples from an area affected by barley stunt disease and from the field experiment, mentioned earlier, on cultivation methods for barley have also been examined. 612

Radioactivity

The Institute radioactivity unit continues to be centred in the Department of Soil Fertility. Since radioisotopes are extensively used in numerous research projects, a major responsibility of this unit is to give advice, services and collaboration to other departments, especially Plant Physiology, Soil Organic Chemistry and Pedology. This frequently requires development and standardization of appropriate techniques and consideration of effects of radiation on the growth, development and metabolism of plants. An account of experience gained over the years in the preparation of radioactively-labelled plant materials for various experimental purposes has been submitted for publication[126]. The factors involved are discussed, including techniques for incorporating radioisotopes into plants, radiation damage, levels of specific activity, and labelling with two isotopes. The specific examples include ^{65}Zn in ryegrass for chemical fractionation studies in relation to animal nutrition, ^{22}Na and ^{36}Cl in beetroot for physiological investigations, ^{59}Fe in wheat grain for a human metabolic study, ^{45}Ca in wheat seed for subsequent germination and examination of calcium distribution in seedlings and ^{14}C in plant material for production of humic substances. A short review[127] of methods for tracing magnesium in plants and

an account of joint work with the Peat and Forest Soils Section of the Department of Pedology on the use of tritium for tracing water movement in drainage studies on a tree plantation[85] have also been submitted for publication. With the aid of improved counting, employing ready-to-use phosphors capable of holding large amount of water, the tritium method has been found to be very sensitive in tracing general movement of groundwater as well as drainage to ditches, and an account of the results is in preparation. 613, 5613, 110, 305, 309, 407

Advisory Work

During the last three years the number of soil samples submitted by the Advisory Officers of the North of Scotland College of Agriculture has increased very substantially from 4700 in 1973-74 to over 5600 in 1974-75 and 7600 in 1975-76. Except for a relatively small number of horticultural samples, 160 in 1975-76, these all came from agricultural land, and the main requirement was assessment of the lime, phosphate and potassium status. Magnesium was also examined in 850 of the 1975-76 soils, while in some samples from glasshouses inorganic nitrogen extracted with potassium chloride solution was measured to assist control of nitrogen nutrition. Trace element problems, involving animal health as well as crop production, continue to be dealt with in collaboration with the Department of Spectrochemistry. Analyses, mainly for cobalt and copper, were carried out on 650 soil samples and nearly 90 crop and herbage samples were examined, normally for cobalt, copper, manganese, molybdenum and zinc. Samples of sewage sludges and distillery wastes have also been examined, especially for heavy metals, to assist enquiries about the use of such materials on agricultural land.

In collaboration with the East of Scotland College of Agriculture and the West of Scotland Agricultural College, 16 soil samples from each of nine major soil series in Scotland, three from each College area, have been interchanged and examined at the three centres by the current advisory soil testing methods. Periodic exercises of this kind are necessary to review implications of soil series and soil properties, to improve and rationalize soil testing procedures, to ensure uniformity of interpretation of results, and to supplement research on laboratory methods for evaluating the nutrient status of soils. 601, 608, 5206

Assistance continues to be given to the Peat and Forest Soils Section of the Department of Pedology in the examination of soils from forest nurseries, involving during the year assessment of the phosphate, potassium, calcium and magnesium contents of 122 samples. 608, 107, 5206

7. STATISTICS

Mr R. H. E. INKSON

The department provides a consultative and advisory service for research projects at the planning stage, and also the consequent facilities for data processing, statistical analysis, model-building and computer programming and operation. The large number of projects featuring in the year's work are associated with all but one of the research packages.

Members of staff have attended meetings of the Biometric Society, the Royal Statistical Society and the British Society of Soil Science. The department has also been represented at an ARC statisticians' symposium on problems arising in service activities, a meeting of the ARC Crop Science Model-Builders' Group and the Forest Soils Discussion Group tour of six forest areas where research work is being undertaken.

Computing Service

The department is responsible for the organisation and use of the IBM 1130 and System/7 computer installation, including the data preparation equipment. Programming advice and assistance have brought a number of new and modified programs into use. Alterations and improvements have been made to statistical programs for general application and the development of program CORRG from CORRX has made additional options available in correlation and regression analysis. 701, 703

Pedology. Progress has continued in the processing and in the display on the plotter, of x, y and z spatial co-ordinates as digitized from previous peat survey maps. Particular attention has been paid to the format on punched cards so that the same data decks can be used with the program packages which have been developed for map analysis, multivariate analysis and data sequence analysis. This situation has led to the construction of a basic framework for the establishment of a peat data bank for Scotland. Vegetation data from a number of sites in a peatland area of Wigtownshire have been processed by phytosociological and clustering techniques with a view to classifying the peatland communities of the area.

112, 701, 703, 5701, 5703

The punching and processing of data from mass spectrometry, X-ray silicate analysis and from the auto-analysis of rainfall, foliage and other samples continues on a regular routine basis.

104, 107, 108, 112, 114, 115, 116, 117, 5703

Spectrochemistry. Additional programs have been developed and put into regular use in the Mössbauer and electron paramagnetic resonance (EPR) studies. In the former, calculations have been made of the electric field gradient arising from the charges within a crystal lattice, and an extension of EPR studies has resulted from the use of a variety of spin-Hamiltonians. 203, 703, 5703

Soil Organic Chemistry. An investigation has been made of the suitability of a program for the identification of amino acids and the calculation of peak areas and percentage composition of the sample. 303, 5703

Soil Fertility. A new group of analysis of variance routines, program QFRUC, has been developed as a modification of the five-factorial program FF to cope with split-plot designs where the sub-plot treatments consist of two factors. Work has also been done to incorporate a missing value estimation routine into a program which deals with a particular type of partial confounding. The calculation of soil moisture characteristics for sample soil cores by the program MOCHA continues on a routine basis. 607, 612, 703, 5703

Soil Survey. A file of 1022 sample sites from the Lanarkshire area has been created with data on location, altitude, slope, aspect, definition of horizons occurring in the sample profile and descriptions of physical properties for each horizon. Statistical summaries of various properties have been made. The punching and data processing service of plant sociological data has continued. 801, 802, 703, 5703

Advisory and Collaborative Work

The collaboration with other departments is of a very closely integrated nature to ensure that appropriate advice is available on the collection and tabulation of data as well as in the planning stages of a project and in the interpretation of results subsequent to statistical analysis. On a wider scale the department has begun work on the establishment of a computer-based soil information system. As well as providing simple access to specific information the system will deal with a range of unresolved questions regarding relationships between many of the soil properties recorded. An inter-departmental working group has already been established and a pilot study has been planned. 703

Pedology. Random sampling schemes have been prepared and routine processing of initial whole tree sampling data has been carried out for a further NPK experiment on Sitka spruce. This completes the setting up of six experiments of central composite design with additional controls in the study of the relationship between tree growth and nutrient uptake. Routine processing and statistical analysis of annual diameter and foliar composition values is carried out for all experiments in the series. The rainfall data, accumulated over the past three years from these experiments, has been processed by a new group of programs, UISGE, UISGM and UISGA with appropriate sub-routines. Multiple regression and spectral analysis methods were used with curve fitting about indicated harmonics to relate tree growth to the cyclical pattern of temperature and rainfall measurements. A joint account of the work shows the oscillations in climatic factors which match those in ring width deviations[28]. 115, 701, 703, 5701, 5703

Data on nitrogen mineralization in peat from planted and unplanted sites have been analysed. A new program was written to deal with the analysis of variance, but standard programs were used for correlations, regression equations and the plotting of data and fitted curves. 116, 5701, 5703

In a water level experiment the air volume and root weight at various depths have been related to the oxygen concentration. The processing of the accumulated data from two glasshouse experiments on Corsican pine has begun using standard programs for the analysis of variance and regression calculations. An account of the work on the cycling of nitrogen in a stand of Corsican pine[24], described in last year's Report, has now appeared. 110, 117, 5701, 5703

A joint account of a study of the prediction of hydroxyl activity from determinations of silica, aluminium and iron[13] has also been published. 105, 5701, 5703

Spectrochemistry. Analyses of variance and covariance were carried out on yield and percentage of grass species from an experiment with different rates of sewage sludge and trace element treatments. 202, 5701, 5703

Soil Organic Chemistry. Standard methods of analysis of variance have been used on data from two factorial experiments. One of these was concerned with the growth of wheat roots and involved the combination of results obtained at different dates, while the other measured amino acids relative to a standard. A method of inverse estimation was used to obtain sugar concentration from optical density and a joint account of the work[44] has been published. 303, 307, 309, 5701, 5703

Plant Physiology. The nutrient content and the catalase and peroxidase activities of potato core sections from heel to rose end have been examined by curvilinear regression to establish the pattern of variation. Joint accounts of this work[109, 108] have been accepted for publication. Experiments of randomized block and factorial design have been concerned with oats, potatoes and tomatoes grown in peat and corn grown in calcareous soil. For all of these, standard methods of analysis of variance have been used to examine nutrient contents, their ratios and relationships. 401, 402, 5701, 5703

Microbiology. Further work has been done on the relationship between numbers of bacteria and various properties of peat and a joint paper with the Department of Microbiology[59] has been published. Comparisons between two soils which have grown barley continuously for different numbers of years have been made in respect of carbon and nitrogen contents, and of the effect of different nitrogen treatments on the incidence of take-all disease. The angular transformation of the percentage infection has been used. The estimation of protozoan populations in numbers per gram of oven-dried soil, with 95 per cent fiducial limits, is carried out on a regular routine basis. 503, 504, 505, 5701, 5703

Soil Fertility. The field experiment programme includes 48 new or continuing experiments with designs ranging from randomized blocks and Latin squares to confounded factorial arrangements and lattice squares. 601, 603, 607, 608, 609, 701, 5701

Linear, quadratic and exponential regression equations have been used in relating the percentage yield for grass, barley and swede crops to soil pH,

and soil pH in turn to the lime status and lime requirement of the soil. The equations have been of value in predicting the effects of different annual liming policies. 608, 701, 702, 5701, 5703

Linear regression equations have also been used in relating crop yields and uptakes of nutrients to soil test values in a number of studies with different crops. In another collaborative investigation, with nine groups of sixteen soils, linear regressions relating different soil test values for several elements have been evaluated and combined for those soil groups which do not show differences in the relationship. 601, 603, 702, 5701, 5703

Further experiments of factorial, confounded factorial and split-plot designs have been planned to continue the detailed study of the pattern of growth and development of barley and swedes. Over 1300 sets of data on physical and chemical measurements on plant parts at various times throughout the growing season and estimates of growth rates have been examined by analysis of variance. Linear, quadratic and cubic response equations have been derived and plotted. 607, 701, 5701, 5703

The relationship between crop yield measurements and the nitrogen and excess base contents of young plants has been examined for different varieties of oats, barley, wheat and swedes. The combined results for several series of experiments have been assessed. 606, 5701, 5703

Soil Survey. A selection of analytical data was provided from eleven soil series in south-east Scotland. The various properties were compared between series for the same horizon and between horizons within series. Another investigation involved the comparison between soil groups and the correlation within soil groups of twenty-two properties measured on soil in three groups—podzols, brown podzolic soils and brown earths. The variability of analytical methods for peaty podzols has been examined. 801, 5701, 5703

8. SOIL SURVEY

Mr R. Grant and Dr R. Glentworth

The retirement of Dr R. Glentworth on September 30th from the post of Head of the Soil Survey of Scotland, which he has held since its inception in 1947, is an appropriate occasion to review the progress and output of the Survey achieved under his guidance.

Coloured soil maps, on a scale of 1 inch to 1 mile, produced by the Survey, are printed by the Ordnance Survey using the sheet areas of their Third Edition projection and since the first of these, Sheet 86 (Huntly) and 96 (Banff) appeared in 1954, the soils of 36 sheet areas have been surveyed and published on 23 soil maps. Four others have been completed and are in the process of being printed. Together these cover an area of 27 840 km² (10 750 square miles) and with a further 8500 km² (3275 square miles) of field work completed on current sheets, nearly one half of Scotland has now been surveyed.

In addition, over 70 special surveys at larger scales have been carried out, ranging from the Island of Rhum (12 000 ha) at 1:25 000 for the Nature Conservancy to Aldroughty Farm (40 ha) at 1: 2500 for the North of Scotland College of Agriculture.

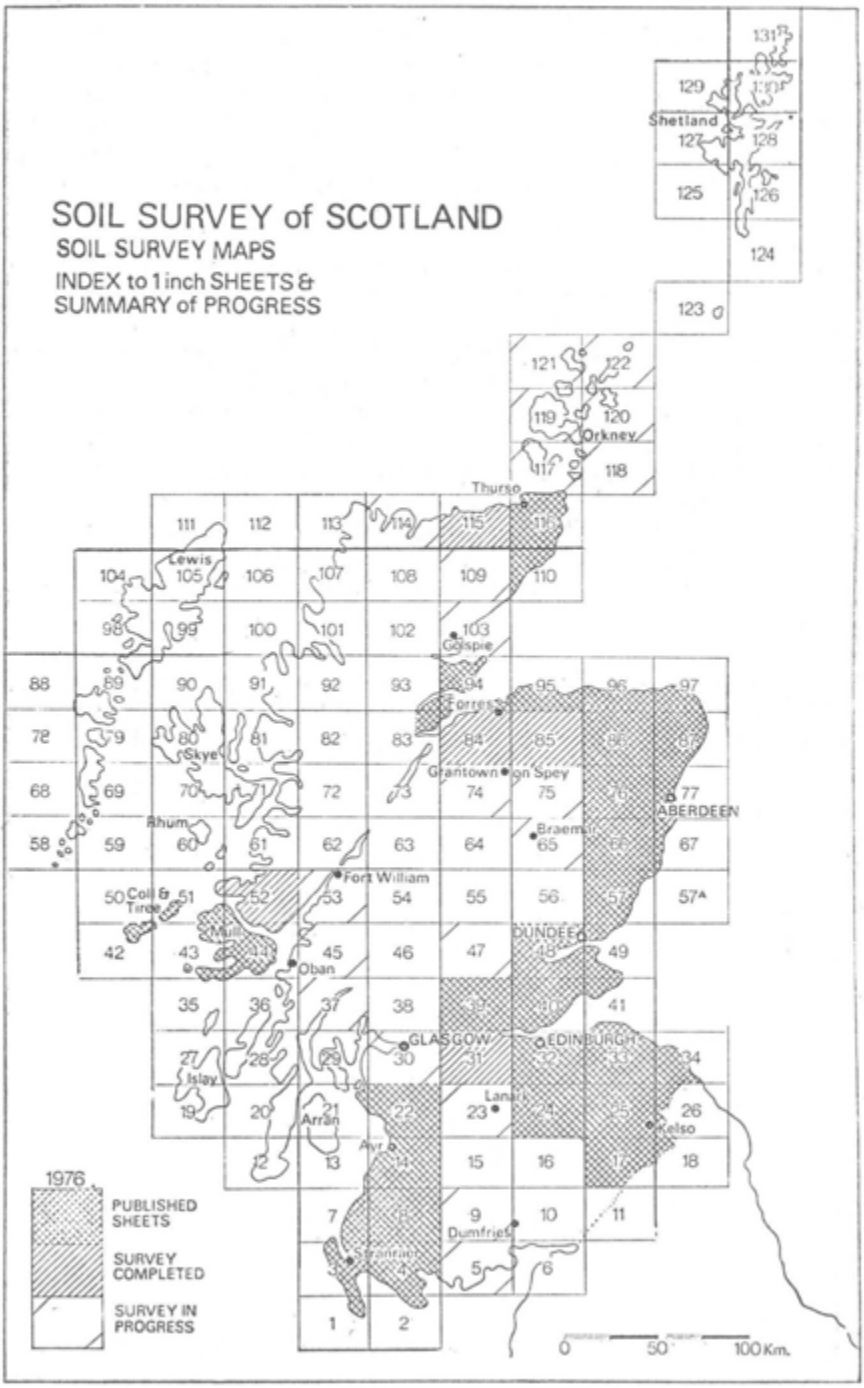
Land Use Capability classification, an interpretation of the soil maps in terms of the limitations imposed by soil, site and climate, was introduced in 1966. To date, 8 corresponding land use capability maps have been published, 2 are in press and a further 4 are being processed for printing. As an aid to the classification, a series of three maps, on a scale of 10 miles to 1 inch, has been published under the general title of Assessment of Climatic Conditions in Scotland.

Systematic soil survey on a scale of 1:25 000 has continued in 10 areas. During the current season 1445 km² (560 square miles) have been surveyed: 115 on Sheets 118, 119, 120, 121, 122 and part 117 (Orkney); 220 on Sheets 115 (Reay), 109 (Auchentoul) and 103 (Golspie); 75 on Sheet 75 (Tomintoul); 100 on Sheet 74 (Grantown); 450 on Sheets 52 (Tobermory) and 53 (Fort William); 85 on Sheet 47 (Crieff); 13 on Sheet 45 (Oban); 40 on Sheet 38 (Loch Lomond); 170 on Sheet 23 (Hamilton); and 175 on Sheets 9 (Maxwelltown) and 5 (Kirkcudbright). Eight special surveys on larger scales have been completed.

Land use capability assessments have been made concurrently with all new soil mapping. Progress continues with the assessment of areas for which soil maps have been published: 200 km² have been classified on Sheet 87/97 (Peterhead/Fraserburgh); 23 km² on Sheet 76 (Inverurie); and 460 km² to complete Sheet 57 (Forfar).

Two hundred and eight soil profiles have been described and sampled for analysis.

Members of staff have attended meetings of the British Society of Soil Science, the British Cartographic Society and the Hill Land Use and Ecology Group. The department is represented on the Ordnance Survey


SOIL SURVEY of SCOTLAND
SOIL SURVEY MAPS
INDEX to 1 inch SHEETS &
SUMMARY of PROGRESS
Shetland
Orkney
Thurso
Lewis
Golspie
Forres
Grantown on Spey
Skye
Rhum
Braemar
ABERDEEN
Fort William
Coll & Tiree
Mull
Oban
DUNDEE
GLASGOW
EDINBURGH
Islay
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Ayr
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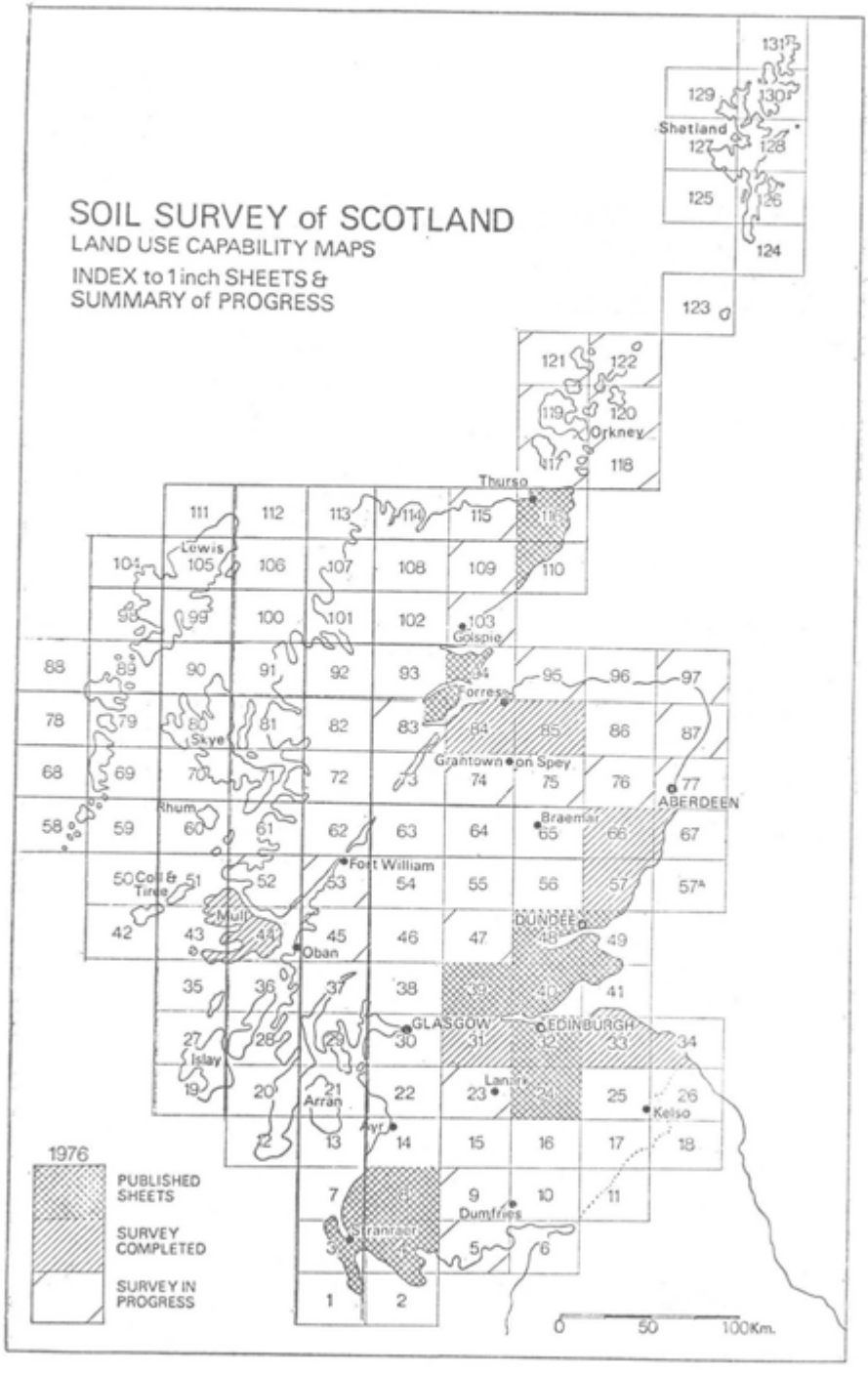
SOIL SURVEY of SCOTLAND
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Dumfries
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Advisory Committee and the Scottish Agricultural Development Council Field Drainage Group.

The considerable interest generated by Land Use Capability maps has resulted in increased demands on time. Two meetings of the Agricultural Development and Advisory Service Working Party on Land Use Capability Classification have been attended. The Working Party are currently considering criteria to be incorporated in revision and extension of the guidelines given in Technical Monograph 1.

In Scotland the Standing Committee on Rural Land Use, established by the Secretary of State, appointed working parties to deal with rural land use in the low ground and uplands of Scotland respectively. The low ground group requested that attention be given to subdivision of Class 3 of the land use capability classification and a technical group under the chairmanship of Mr J. Ferguson (D.A.F.S.) is currently considering ways of implementing this request. Two meetings have been held.

The hill land group met twice and has established a technical group (J. S. Bibby, Chairman) to consider the collection of data and development of a satisfactory system of land classification for the uplands. 801, 802, 804

Sheets 118, 119, 120, 121, part 117 (Orkney Islands)

Approximately 115 km^2 (44 square miles) have been surveyed and 23 profiles described and sampled.

Soil and land use capability mapping took place in the parishes of Birsay, Sandwick and Harray on the West Mainland of Orkney and on the island of Rousay.

Soils of the Thurso Association dominated the West Mainland landscape with podzols of the Bilbster series the most frequently encountered; areas of the Thurso, Olrig and Camster series were also mapped. Mappable areas of deep-topped 'plaggenboden' soils were found and were placed provisionally in L.U.C. Class 3c. It appears that revision of areas of similar soil assemblages will be necessary in respect of these soils.

Fraserburgh series was mapped around Birsay Bay and Fraserburgh series and Heilen complex around Bay of Skaill, in shelly deposits. Small areas of basin peat and peat-alluvium complex were mapped, the peat-alluvium deposits frequently incorporating marl beds.

Areas of salt-affected soils were mapped along the north and north-west seaboard of the West Mainland; such soils are poorly drained, sometimes with an organic surface horizon, developed in strongly weathered drift or rock and with a strong, coarse columnar structure. The soils immediately adjacent to the cliff edge have surface horizons that are somewhat alluvial in nature, with wave-wash a suggested agent. These soils could be described as saltings but other salt-affected soils have been described provisionally as the maritime phase of the Thurso series.

Soils of the Thurso and Canisbay Associations and peat were mapped in Rousay. The soils of the Thurso Association occur generally within com-

plex units developed on stepped hillslopes. Five complex units were considered:

(i) Camster series (shallow and normal phases) with Bilbster series (shallow and normal phases) and rock outcrops (hamars) with Olrig or Thurso series on flats. Flush and creep-soils also occur within the complex which has been named, provisionally, the Westside complex.

(ii) Similar soil assemblage as in the above complex but with a greater proportion of Olrig or Thurso series on the generally better defined flats. This complex is more open, developed on less steep slopes and has been encountered before in Westray where it was named, provisionally, the Fitty complex.

In both these complexes there is a noteworthy absence of peat on the flats.

(iii) A flush complex of Olrig series, creep-soils, Camster series with rock outcrops and some thin peat. The complex which is developed on a steep north-facing slope is of limited extent and has been named, provisionally, the Lythe complex.

(iv) Olrig series, usually shallow, with Camster series (shallow phase) on isolated narrow ridges; complex named, provisionally, the Moan complex.

(v) Thin peat and Olrig series, essentially a complex of cut-over and eroded peat. Such a complex has been encountered on the West Mainland and is named, provisionally, the Huntis complex.

A small area of oroarctic podzol was mapped within the Thurso Association on Knitchen Hill (225 m, 746 feet); the highest hills of Rousay are covered in eroded blanket peat. Salt-affected soils were found along the north-west coast.

Soils of the Canisbay Association were mapped on the eastern slopes of Knitchen Hill and in the valley of Sourin. Peaty gleyed podzols (Warth series), peaty gleys (Canisbay series) and noncalcareous gleys (Tresdale series) were found together with a freely to imperfectly drained cultivated podzol named, provisionally, Braebuster series.

Deep and shallow peat was mapped over much of the interior of Rousay with eroded and cut-over phases being noted. 801

Sheets 103 (Golspie), 109 (Auchentoul) and 115 (Reay)

Approximately 222 km² (84 square miles) were surveyed and 13 soil profiles described and sampled.

The main district mapped lies immediately to the north of the River Brora and includes 57 km² (22 square miles) of land previously looked at in 1966 but which required a re-examination in the light of recent work on soil complexes. Most of the district consists of moorland at a general altitude of between 120 and 270 m (400 and 900 feet), underlain by Moinian granulites with some granite-schist injection complex rocks forming slightly higher and more hilly land in the west. The soils are predominantly peaty podzols (Gaerlie series) and peaty gleys (Hythie series) of the Strichen Association, while deep blanket peat occurs extensively. Strathnaver complex and an un-

named complex of Gaerlie series, Hythie series and shallow peat are common mapping units. A complex of freely drained podzols and poorly drained peaty gleys (Dalvina complex) occurs on the moundy steeper valley sides of the Black Water and River Brora, settlement and cultivation having at one time taken place on the better drained parts. These areas of Dalvina complex are land use capability Class 5 land, the remaining areas of moorland being Class 6. The eastern part of the district is hilly, ranging in altitude from 30 m (100 feet) in the valley to over 518 m (1700 feet) and underlain by conglomerates and sandstones of Middle Old Red Sandstone age. Peaty podzols (Berriedale series) with some peaty gleys (Knockally series) of the Berriedale Association, together with deep and shallow blanket peat, are the main soils present, a common mapping unit being a complex of Berriedale series and shallow peat. All this area of peat and peaty soils forms Class 6 land. Humus-iron podzols, commonly under birch woodland, are present on the steep slopes above Loch Brora and comprise Class 5 land.

The second district mapped consists of Forestry Commission land near the head of Strath Naver. The soils belong to the Strichen Association and are predominantly peaty gleys (Hythie series), some with indurated subsoils, and peaty podzols (Gaerlie series). Strathnaver complex and Dalvina complex occur on the moundy morainic topography in the northern part. The area of Dalvina complex has been placed in Class 5, but most of the district is Class 6 land. 801

Sheets 87 (Peterhead) and 97 (Fraserburgh)

The land use capability of about 200 km² (80 square miles) of this area has been assessed. Most arable land has been included in Classes 3s and 3w, the main exceptions being shallow soils (Class 4s) and a narrow coastal strip of blown sand liable to erosion (Class 4e). Two areas of deep and only slightly stony soils in the valley of the South Ugie Water, between Old Deer and Mintlaw, have been included in Class 2s. Most of the basin peats have been provisionally assessed as Class 5w. 801

Sheet 76 (Inverurie)

Work has continued on the land use capability assessment of Sheet 76 (Inverurie) and approximately 23 km² (9 square miles) have been classified mainly in the Insch Valley. 801

Sheet 75 (Tomintoul)

About 75 km² (30 square miles) have been surveyed in upper Donside, in the catchment areas of the Ernan Water and Water of Nochty. Peat and peaty podzols are the most extensive soils and Foudland and Tarves are the most extensive associations. Foudland soils have been mapped on the slaty rocks of the Ladder Hills and Tarves soils on mixed drift derived from basic igneous and acid rocks. The latter association is much more widespread than would be expected from the geological map, because of numerous narrow basic igneous dykes which outcrop along the bands of slate and quartzite. Soils of the Leslie, Insch and Durnhill Associations have been

mapped on ultrabasic, basic, quartzite parent materials respectively. Many of the Leslie Association soils are peaty gleys, and humus-iron podzols and brown forest soils are widespread on the Insch Association. 801

Sheet 74 (Grantown-on-Spey)

In addition to systematic soil survey, all site investigations for the new A9 trunk road were completed (reported under Special Surveys).

About 100 km² (40 square miles) have been surveyed, 41 profiles described and sampled, 18 in collaboration with the Department of Soil Organic Chemistry. Over the last four years this project has involved approximately 60 podzol profiles, totalling some 700 samples. One aspect of the investigation is the establishment of a chronosequence in podzol development in the Central Highlands.

During the current field season mapping has been concentrated in two main areas. In the east, mapping has been virtually completed along the boundary with Sheet 75 (Tomintoul) and a joint programme undertaken o ensure correlation. Much of the northern sector consists of a moundy outwash plain with extensive areas of basin peat in the hollows. The sands and gravels form the parent material of the Boyndie and Corby Associations described previously. From Lurg to Auchernack large spreads of gravelly loamy sands have been mapped within the Dulsie Association. Normally these deposits form low subdued mounds, but on Carn Na Loinne they also form a veneer over shattered schist rock on the flanks and through the cols. Around the summits a complex of rock and the Derraid series of the Strichen Association has been mapped. The majority of all these mineral soils are freely drained humus-iron podzols, or, occasionally, peaty podzols. Peaty gleys are usually limited to small areas on concave slopes below spring lines.

Soils of the Boyndie and Corby Associations are also widespread in Rothiemurchus Forest, but the dominant profile is an iron podzol. Typically an LF horizon, 5 to 15 cm thick, overlies an ash grey A_2 horizon which may be up to 20 cm thick resting directly on a strong brown (7·5YR5/6) B_2 horizon. Similar iron podzols have been mapped in the Loch Garten area. Near the upper tree limit the iron and humus-iron podzols are rapidly replaced by peaty podzols and peaty gleyed podzols.

The southern sector is dominated by the Cairngorm Mountains where mapping has been extended northwards to Abernethy. On Mam Suim alpine soils have been mapped on schist, analogous to those previously described on granite. Following the correlation with Sheet 75 (Tomintoul) it has been tentatively agreed to use two primary complexes for high-level mountain soils, (1) shedding sites dominated by alpine podzols, (2) receiving sites in col or corrie situations characterized by gleys. The use of specific phases for patterned ground, tors, boulder lobes, etc., requires further evaluation. Around Loch Avon and in the Lairig Ghru the granite crag and scree slopes have been accommodated within the Kingairloch Complex. Correlation of unstabilised or partly stabilised scree slopes below convex summits without apparent rock outcrops, has still to be determined.

The second mapping area extends westwards from the River Findhorn into the Northern Monadhliaths. All the soils encountered have been described in earlier reports. 801

Sheet 57 (Forfar)

The land use capability assessment for Sheet 57 (Forfar) has been completed with the classifying of the remaining 460 km² (180 square miles) to the north and north-west of the River South Esk. 801

Sheets 51 (Coll), 52 (Tobermory) and 53 (Ben Nevis)

Approximately 450 km² (174 square miles) have been surveyed in the parish of Moidart and between Glen Gour and Loch Eil. In addition, 180 randomly selected morphological soil descriptions from 9 sample areas in 4 soil associations have been taken to aid the definition and description of major complex units in Ardnamurchan and Morvern and 29 profiles have been sampled for analysis at the Institute.

The area surveyed is almost entirely underlain by schists and gneisses of the Moinian Assemblage, apart from a small body of augen-gneiss associated with the Strontian granite. However, the soils and complexes developed there have shown strong affinities to those found on schist and have been mapped as such.

The region has been deeply dissected by glaciers giving rise to many long low-lying valleys and has several summits over 760 m (2500 feet). The area west of Loch Shiel is rugged while that to the east is similar but has more subdued topography near Loch Eil. Soils are peaty gleys and peat with less extensive peaty podzols. Small areas of Corby Association soils and alluvium provide arable ground, mainly near the shores of Loch Linnhe, Loch Eil and in lower Glen Moidart.

A draft key for Sheet 52 has been completed and circulated for discussion. Some correlation work within soils of Strichen Association remains to be carried out before the draft can be finalized. No new soil associations have been found but several new series developed on stony, humose, colluvial drift have been introduced.

A report on the soils and land use capability of 834 km² (322 square miles) of Ardnamurchan and Morvern was prepared for the Highlands and Islands Development Board to accompany the map submitted in 1975. Of that area 1 per cent was included in Class 4 (arable or potentially arable), 22 per cent in Class 5 (reclaimed or partly reclaimable) and the remainder in Classes 6 and 7 (unimprovable land). The figure for reclaimable ground calculated from the map is an over-estimate, as half of the land included within complexes making that total would probably be unsuited to reclamation. The figure is probably closer to 11 per cent. 801

Sheet 47 (Crieff)

Approximately 85 km² (34 square miles) of new mapping has been completed during the current field season. This included 35 km² (14 square miles) of the important and complex Highland Border Fault zone north of Crieff comprising Ochtertyre, Glen Turret and Monzie Castle estates. The

soil pattern is extremely complex and many of the soils are prone to trace-element deficiencies, especially of cobalt. Those encountered have all been described previously and have been included in the Balrownie, Corby, Forfar, Gourdie, Callander, Darleith, Sourhope, Foudland and Strichen Associations. New series have been established in the Gourdie Association to accommodate podzols, peaty podzols and peaty gleys which were not encountered further east in the area where the association was first described.

The remainder of the mapped area is centred on Glen Quaich, a fairly typical east-west aligned Highland glen west of Amulree. There are well developed sequences of soils from immature alluvial gleys in the valley bottom at about 900 feet passing rapidly into acid brown earths up the steep slopes of the valley sides as high as 1400 feet where the change to gentler slopes coincides with a narrow podzol zone which gives way very quickly at about 1500 feet to peaty podzols, peaty gleys and peat. Between 1500 and 2250 feet peat is predominant, especially on the rounded hills, and is frequently eroding. The rocky summits and slopes support podzolic and peaty ranker soils while the rounded summits are capped with shallow montane podzolic soils.

Correlation has been established between the mixed drift occurring north and west of Comrie which includes various types of acid schists and granitic rocks, and the mixed acid drift of north-east Scotland which forms the parent material of the Aberlour Association. New series to accommodate some major soil subgroups not separated in north-east Scotland have still to be established.

Four soil profiles from the Ben Lawers area and a brown earth profile under oakwood near Comrie have been sampled for micromorphological examination. Eight examples of the Balrownie series have been described and sampled for the measurement of physical properties in collaboration with the Soil Fertility Department. This sequence in Strathmore extended from near Crieff in the west through Perth to near Brechin in the east and was remarkably uniform in morphology over the whole area. 801

Sheet 45 (Oban)

Survey near Oban, started in 1969, was revised and extended during August following a request from the Department of Agriculture for Scotland and the Director of Physical Planning, Argyll and Bute District, for information on soil and land use capability for inclusion in a development plan for Oban and Benderloch. A further 13 km² (5 square miles) has been surveyed principally on the raised beaches and outwash fans of Connel and Benderloch. The soils are similar to Corby series but show strong andesitic influence. 801

Sheet 38 (Loch Lomond)

Approximately 40 km² (16 square miles) of new mapping was undertaken to complete the 1:25 000 sheets on the western margin of Sheet 39 (Stirling) so that the 1:25 000 soil maps comprising sheets NS69 and NN60 can be prepared for limited circulation. The 2 km wide strip included some very variable terrain from the drumlin belt north of the Campsie Fells scarp across the boulder clay lowlands flanking the flat Forth valley to the High-

land Boundary Fault zone immediately west of Callander. The soils encountered were included in the Sorn, Kippen, Balrownie, Carbrook, Stirling, Doune, Callander and Foudland Associations. 801

Sheet 23 (Hamilton)

Approximately 170 km² (66 square miles) have been surveyed around Lesmahagow, East Kilbride and to the south of Forth and Wishaw. With the exception of small areas east of Eaglesham and south-west of Hamilton this completes the mapping of grid squares NS65, 73, 85 and 95.

Most of the soils mapped belong to the Rowanhill Association but the following series, from associations of the same name, have also been mapped: Darleith, Darvel and Kilmarnock. Between Stonehouse and Lesmahagow soils of the Balrownie Association have been mapped on till from Lower Old Red Sandstone sediments. The sandstones, however, have a varied lithology; some are red, brown or pink, poorly cemented, quartz rich sandstones and frequently give rise to the Buchanyhill series. Other examples are dense, fine-grained grey and pinkish grey sandstones containing fragments of greywacke and on drift from these rocks the Linhope series (Ettrick Association) has been identified.

The western part of grid square NS73 is underlain by Silurian rocks of the Lesmahagow inlier, consisting of grey flaggy greywackes, multicoloured mudstones and yellow and red sandstones. These rocks give rise to soils of the Ettrick Association of which the Altimeg, Dod, Ettrick, Hardlee, Kedslie and Linhope series are the most common. Blanket peat covers most of the higher parts of the hills of this inlier.

The soil data set for grid square NS84, reported last year, has now been edited and stored on disc on the IBM 360/370 computer at Newcastle. The program GRIDCAMAP has been used in conjunction with a modified IBM 1403 line printer with special print-chain and an overprint facility to map at a scale of 1:39 370 many of the soil properties originally recorded. Combinations of properties and environmental data have been represented, after calculation, as maps of crop suitability and land use capability. The files have also been set up for statistical evaluation on the Institute's computer and on EMAS, the Edinburgh Regional Computing Centre's multi-access system, where it is hoped that an improved method of automated mapping including boundary checking and location, can be pursued. 801

Sheet 5 (Kirkcudbright) and 9 (Maxwelltown)

Surveying has been continued this season in the Nith Valley, from Dumfries northwards to Carronbridge, where approximately 175 km² (70 square miles) have been mapped. In addition 47 profiles have been described and sampled mainly from areas mapped in previous years.

The alluvial tracts along the River Nith are generally protected by earth banks from flooding and the land is amongst the most fertile in the area. The soils show little or no differentiation of pedologic horizons and comprise deep, brown, organo-mineral loams, fine sandy loams and silt loams overlying gravels at depths generally of 50 cm to 1 m. The internal drain-

age is free or moderately good and the correlation of these soils with the Peebles series is pending.

Bordering the alluvial areas spreads of fluvioglacial materials, mainly gravels, are extensive in the valley bottom especially around Thornhill and Kirkton. The stone content is generally high with an abundance of large cobbles in some areas, and is mainly of greywacke origin. In some places red staining on the stone surfaces is probably inherited, the stones having formerly been incorporated in New Red Sandstone strata of the Thornhill or Dumfries basins. The soils are free-draining and have been placed in the Yarrow Association. In dry seasons crops on these soils are likely to suffer severely from drought.

On the lower hill slopes around the Thornhill and Dumfries basins the reddish brown drifts and tills are derived mainly from sandstones of New Red Sandstone age, with some admixture of greywackes, and, in small areas near Thornhill, the addition of Carboniferous sandstones. Most of the drifts have been strongly 'water-worked' in the upper layers and are of sandy loam or loamy sand texture. They carry free-draining soils. A few areas of unmodified reddish brown clay loam till were encountered near Tibbers and Hoyfield. The soils have been placed in the provisionally established Holywood Association.

The upper slopes are underlain by Silurian greywackes and shales but their derived drifts and tills generally have a reddish brown colour probably caused by small amounts of materials carried from the nearby red sandstone. The soils have been placed provisionally in the Ettrick Association as being analogous to the 'red' Ettrick Association soils described in the Kelso and Lauder areas of south-east Scotland.

West of Penpont mapping was continued along the lower reaches of the Scour and Shinnel Waters to link up with previously surveyed areas. The underlying rocks are Silurian greywackes and shales and their derived drifts are generally thin, mainly stony loams and sandy loams, grey or greyish brown in colour. The brown forest soil, Linhope series of the Ettrick Association, is the predominant soil, occurring both as the series map unit and as a major component in complex map units. 801

Special Surveys

A9 Trunk Road. The site investigations undertaken at the request of the Scottish Development Department have been completed. In the final phase of the Avielochan-Slochd sector 53 pits were excavated to depths ranging from 2 to 12 metres. The majority of these profiles revealed fluvioglacial bedded sands and gravels, frequently resting directly on shattered schist or granitised schist. Near Carrbridge, however, a veneer, about 2 m thick, of ill-sorted gravelly loamy sands belonging to the Dulsie Association, was underlain by more than 8 m of extremely indurated mixed schist and granite till of the Aberlour Association. Due to the intensity of this induration during excavation, explosives had to be used on one occasion to dislodge large erratic boulders.

At the southern end of the Slochd and within 100 m of outcropping rock a deposit of highly weathered granitised schist about 5 m thick was recorded.

At the request of the North of Scotland College of Agriculture advice and assistance have been afforded in several reclamation projects — these include:

Kyllachy Estate. A 1:10 000 soil survey was carried out to assist the preparation of a new management plant. The area occupies 15 km² and ranges westwards from the alluvial haughs of the River Findhorn to the blanket peat of the Monadhliath Mountains. Areas suitable for grassland reclamation were identified within the foothills and graded with regard to soil limitations under different reclamation methods.

Corrybrough Estate. Areas suitable for both arable and grassland reclamation were examined. Data was supplied for incorporation within a College report submitted to the proprietor.

Rothiemurchus Estate. Two separate projects involve the drainage and cultivation of alluvial areas at Loch Pityoulish and at Doune Farm on the River Spey.

At the latter project 13 profile pits were examined to determine soil conditions. Subsequently slotted pipes were installed to a depth of about 1.5 m to record water table fluctuations over a complete year. The design and the extent of the reclamation will eventually be based upon the results.

Lephinmore Farm. Survey of Lephinmore Farm (Hill Farming Research Organisation) on Sheet 37 (Inverary) was concluded during October. Morphological descriptions have been taken at 100 m intervals (1190 inspection points) and the results incorporated into a feature card data bank. Soils of Boyndie, Corby, Darleith and Strichen Associations have been encountered in addition to extensive peat deposits. Apart from the fluvioglacial gravels of Corby series close to the steading, soils of Strichen Association predominate. The wetter soils of the association are more humose and have a higher proportion of fine sand than those described from north-east Scotland. Above 91.5 m (300 feet) the soils are dominated by peaty gley (Hythie series) and peat.

The Moinian rocks, described from Sheet 52 (Tobermory), give stonier and more humose soils than those derived from the Dalradian rocks on Sheet 37. Further correlation work and survey is required to elucidate this point.

A map has been produced for restricted circulation at a scale of 1:10 560, and information derived from this and from the data store has been supplied to H.F.R.O. Also using the data store, a project has been initiated to produce, at low cost, coloured single factor maps and maps showing combinations of factors regarded as significant by user organisations.

Lochgilphead. At the request of the Director of Physical Planning, Argyll District, a survey of the environs of Lochgilphead was undertaken to provide information on soils and land use capability for inclusion in the town plan. Peat and peat alluvium occupy the strath to the north-west of the town, but the remainder of the area consists of soils developed on a red till composed of mixed Highland schists and Old Red Sandstone rocks. Provisionally

assigned to Balrownie Association and containing a high percentage of fine sand, the till has been partly modified by water seepage on the upper slopes and by washing under marine conditions on raised beaches. Climate restricts the range of crops which can be grown on farms near Lochgilphead and the highest land use capability class allotted was 4. Compared with much of the Argyll mainland outside Kintyre the land is, however, of good quality.

Oatridge Farm. A detailed soil survey of Oatridge Farm (Oatridge Agricultural College), West Lothian, was carried out at a scale of 1:2500 and the completed maps and extended legend are at present being prepared by the Cartographic Section. The farm covers 285 ha, but several contained small parcels of land not owned by the College, amounting to some 30 ha, have been included.

Oatridge Farm is represented on the published 1:63 360 soil map (Sheet 32) as mainly Highfield series with small areas of Darleith series and Dalmahoy complex (Darleith Association) and Myreside series. The detailed survey has confirmed these soils, but revealed areas of Caprington, Rowanhill and Sauchieburn series (Rowanhill Association) together with small patches of Heavyside, Macmerry and Waterton series near water courses. Stony, clayey, steep and shallow phases of certain series have been distinguished.

The farm was surveyed using data collected at points of inspection on grid intersections at 40 m intervals supplemented by further points, subjectively sited, where necessary. The data were recorded on voice-tapes and translated later into alpha-numeric form for computer storage. Several single factor computer maps at scales of 1:16 000 and 1:8000 have been produced using GRIDCAMAP as described above.

Gas Pipeline Survey. At the request of the British Gas Corporation a survey was conducted along the track between Roberton, Lanarkshire, and Canonbie, Dumfries-shire proposed for the installation of a gas pipeline. Information was supplied concerning soil type, natural drainage and the nature of the subsoils with particular emphasis on the extent and location of any peat deposits encountered.

Vegetation Surveys

Revised tables of the vegetation of the Lowland and Southern Upland Regions have been prepared for discussion with Professor R. Tüxen of West Germany. Additional material collected by Professor Tüxen, Professor J. M. Géhu and Dr J. Tüxen can be included to extend that gathered by the Soil Survey.

A paper on the place of climate in soil and land use classifications was prepared and presented to a meeting of the Soil Survey of England and Wales at Silsoe. Part of the material for this paper, modified with special reference to Scotland, has been published[65].

A short paper in French was written on one of the pioneer communities on the gravels of the River Avon at Tomintoul. This has been accepted by Documents Phytosociologiques at Lille for publication[128].

The monograph on the Plant Communities of the Lowlands and Southern Uplands of Scotland has been published[66]. The descriptive bulletin[67] to accompany the vegetation map of the Nairn and Cawdor district has also been published.

Collection of phytosociological records of the vegetation of the projected vegetation map of the Cairnsmore of Fleet area has continued. These will provide the main basis for the setting up of the mapping units.

Recording of the vegetation of the mainland areas of Sheets 51 (Coll) and 52 (Tobermory) has been completed. A further set of phytosociological records has been collected in the Orkney Islands and, together with those collected in 1975, will provide the material for the chapter on vegetation in the soil memoir of the area. In addition, similar records were made at the 1 km national grid intersection points on the islands of Westray, Sanday and Rousay (Sheets 119, 120, 121 and 122). These records will allow statements to be made about the vegetation on a quantitative as well as on a descriptive basis.

In collaboration with the Soil Survey of England and Wales a reconnaissance was carried out to establish the boundaries of the sub-zones of oceanicity in England and Wales 802

Soil Micromorphology

During the year, the backlog of soil materials collected for micromorphological studies has been processed and over 250 soil thin sections have been prepared.

The presence of pores, filled or partially lined with oriented clay, has frequently been noted in thin sections prepared from a wide variety of Scottish soils, including Brown Forest Soils, Podzols, Peaty Podzols, Sub-alpine Podzols, Alpine Soils and Gleys. Work is currently in progress to clarify the conditions under which the clay has been mobilised, translocated and redeposited, at various times throughout the present cycle of soil profile development.

Two papers have been published. One is a technical note on an attachment for lapping consolidated materials with particular reference to the preparation of soil thin sections[68], and the other describes some genetic characteristics of the freely drained soils of the Ettrick Association in East Scotland[69]. A paper entitled "Three soil profiles from Elephant Island, South Shetland Islands" has been accepted for publication in the British Antarctic Survey Bulletin[129]. 804

Other Survey Work

The department has continued to collaborate with the Department of Agriculture and Fisheries for Scotland and with the three Scottish Colleges of Agriculture, mainly on projects related to field drainage. A contribution has been made to a College publication on the subject[130]. A number of talks and field demonstrations have been given to staff of these organisations, to local societies and to students of St Andrews, Strathclyde and Liverpool Universities and Notre Dame College of Education, Glasgow. Many requests for soils information from Regional and District Councils, schools, farmers, individual students and members of the public have been dealt with.

Liaison has been maintained with the Forestry Commission, the Nature Conservancy Council, the Institute of Terrestrial Ecology, the Hill Farming Research Organisation, the Highlands and Islands Development Board, the Countryside Commission and with other departments of the Institute.

A paper on indurated layers has been published[70] and a paper on the recording and organisation of soil survey field data for computer areal mapping has been submitted for publication[131]. 801, 802, 804

An account of the soils of the district has been prepared for inclusion in the revision of the Burn Guide to be issued by the Dominion Students' Hall Trust[132].

Maps, Memoirs and Cartography

The 1 inch Soil Survey map covering combined Sheet 40/41 (Kinross/Elie) has been published. Colour proofs of the Soil Survey maps for combined Sheet 84/94 (Nairn/Cromarty) and the Land Use Capability maps of combined Sheets 33/34 (Haddington/Eyemouth), 40/41 (Kinross/Elie) and 66/67 (Banchory/Stonehaven) have been corrected and returned to Ordnance Survey for final printing.

A scribed negative and colour model for the Soil Survey map of Sheet 31 (Airdrie) has been submitted to Ordnance Survey for colour proofing. The negatives of Soil Survey combined Sheet 85/95 (Rothes/Elgin) and Land Use Capability Sheet 31 (Airdrie) have been scribed and colour models are being prepared. A coloured manuscript map of Land Use Capability Sheet 57 (Forfar) has been prepared and this is being checked. A coloured manuscript map of Land Use Capability combined Sheet 84/94 (Nairn/Cromarty) has been received.

The following limited circulation maps have been prepared: provisional Land Use Capability maps of Dumfries and Galloway Region, Fife Region and Lothian Region on 1:250 000 scale; soil maps of Crichton Royal Farm, Dumfries, on both 1:2500 and 1:10 000 scales, of Mar Estate, Braemar on 1:25 000 scale, and of Lephinmore Farm, Argyll, on 1:10 560. A set of seven strip maps covering 76 km of a pipeline route in Southern Scotland was prepared for the British Gas Board.

Twelve members of the British Cartographic Society visited the Department in connection with the 1976 B.C.S. Technical Symposium held in Aberdeen.

A paper on the design and production of soil maps has been published[71].

The memoir to accompany Sheet 48/49 (Perth/Arbroath) has been published[72]. 801

Soils of Lower Strathspey

Field mapping, editing and correlation of the 1:25 000 scale sheets required in the production of the 1:63 360 scale soil and land use capability maps of Sheet 85 (Rothes) have now been completed and a preliminary account of the area is presented below.

Sheet 85 (Rothes) covers about 1120 km^2 (432 square miles) within the former counties of Aberdeenshire, Banffshire and Morayshire. Under present administrative arrangements it forms part of the Grampian Region,

though a small part in the south-west corner near Grantown-on-Spey is within the adjoining Highland Region.

The principal centres of population are at Keith in the Isla Valley, Dufftown at the junction of the Dullan Water and the River Fiddich, and Craigellachie at the junction of the Fiddich and the River Spey. Archiestown, Charlestown of Aberlour and Rothes lie close by Craigellachie in the Spey Valley, and Dallas is in the mid part of the Lossie Valley. Elgin, Forres and Fochabers lie just beyond the northern boundary and Grantown-on-Spey is a few miles beyond the south-west corner.

The area can be subdivided into five landform regions, all of which extend beyond the boundaries of Sheet 85.

1. The Moray Coastal Zone
2. The Speyside Hills
3. The Eastern Hills
4. The Spey Valley
5. The Eastern Foothills

A sub-triangular strip of country along the northern margin, extending from Newtyle Forest to the Spey Valley by Fochabers, has been included in the Moray Coastal Zone. The ground surface is very irregular, rising from the '100 foot' (30 m) beach level beside Forres over the 180-240 m (600-800 foot) Monaughty Ridge down through the valley of the Black Burn and on to Hill of Wangie. Arable land and planted woodland predominate, though there is still some open heather moorland along the summit and north-facing slopes of Hill of Wangie. An oak charcoal patch found in the B horizon of the contemporary podzolic soil profile at 220 m (725 feet) on Hill of Mulundy is suggestive of the former presence of deciduous forest. This material is similar to an oak charcoal horizon found on the buried land surface below a Neolithic barrow near Fochabers. The present day climate of the Moray Coastal Zone, in terms of the Birse system of assessment, may be summarized as fairly warm moist lowland and foothill, moderately exposed with moderate winters to warm dry lowland, moderately exposed with rather severe winters.

In the region of the Speyside Hills most of the ground lies between 275 and 520 m (900-1700 feet). It is an area of bleak heather moorland and blanket peat spread out over the west, central and south parts of the Sheet. South of the Spey the ridges of Creag an Tarmachain and Corriehabbie rise to about 640 and 700 m (2100 and 2300 feet). These ridges together with the solitary mass of Ben Rinnes (840 m, 2755 feet) form a mountainous subdivision which is more reminiscent of the high country to the south on Sheet 75. Arable land is restricted to Glen Rinnes, Glen Rothes and the footslope area just north of Grantown-on-Spey, together with scattered upland farms and crofts along the northern fringe and within minor tributary valleys of the Spey. This is an area of predominantly cool rather wet lowland, foothill and upland, exposed with rather severe winters, but also includes cool wet foothill and upland and very cold wet upland and mountain, very exposed with very severe winters on the high mountain ridges.

The Eastern Hills have been separated from the Speyside Hills along the watershed between the Spey and the Deveron. They are a part of the region described as the Slate Hills in the memoir to Sheets 86/96, but on Sheet 85 include basic and ultrabasic rocks as well as slaty metamorphic rocks continuous with those on 86/96. Climatically the Eastern Hills are simply an extension of the area of the Speyside Hills.

The Spey Valley forms a deep winding trough 48 km (30 miles) long which crosses the Sheet from Grantown to Fochabers. There is a high concentration of farmland interspersed with planted woodland extending up the valley sides to about 300 m (1000 feet), and the concentration of stone circles on the river terraces around the Spey-Avon junction confirms that this has been a preferred site of human settlement for at least 5000 years. The Spey Valley includes fairly warm moist lowland and foothill which is sheltered with moderate winters in the lower reaches, and sheltered with rather severe winters in the upper reaches and in the tributary Avon Valley.

The Eastern Foothills are a continuation of the Banffshire Foothills region of Sheets 86/96 extended westwards as far as Ben Aigan and the Spey Valley. The ground lies mostly below 300 m (1000 feet). Vigorous effort has been expended in times past to break in and develop agricultural land though the climate and topographic pattern are less favourable than those of the Moray Coastal Zone or the Spey Valley. Extensive Forestry Commission plantations, which include some tracts of former arable land, now cover Whiteash Hill, Hill of Ordiequish, Hill of Mulderie, Cairds Hill and parts of Hill of Towie. The only remaining area of open moor and blanket peat in this region is found in the extreme north-east corner of the Sheet. There are local gradations of climate from fairly warm moist lowland and foothill, moderately exposed with moderate winters to cool rather wet lowland foothill and upland, moderately exposed with rather severe winters and locally exposed with rather severe winters.

The geological succession is:

Recent	Peat and Alluvium
Pleistocene	Solifluction deposits
	Fluvioglacial sands, gravels and slits
	Till

Sedimentary Rocks

Old Red Sandstone	
Upper	Sandstones
Middle	Sandstones and conglomerates

Metamorphic Rocks

Banffshire Series	Quartzite
	Schistose Grit
	Limestone
	Graphite Schist
	Clay Slate and Phyllite

Central Highland Granulites
- Mica Schist
- Granulitic Quartzite, Quartz-Mica-Schist and Flagstone
- Undifferentiated Schists and Gneisses

Igneous Rocks

Contemporaneous Andesites of Old Red Sandstone Age

Post-foliation
- Lamprophyre
- Diorite
- Granite

Intrusive

Pre-foliation
- Serpentine
- Gabbro
- Epidiorite and Hornblende-Schist
- Foliated Granite or Augen-Gneiss

The metamorphic rocks of the Banffshire Series and all the igneous rocks are found on the eastern side of Sheet 85, and the Central Highland Granulites lie further west. The sedimentary rocks of Old Red Sandstone age are concentrated on the northern edge of the sheet particularly around the lower reaches of the Spey with smaller isolated outcrops between Glen Latterach and Forres.

The solid rocks are largely masked by a surface veneer of glacial till, drift, moraines, fluvioglacial outwash and solifluction deposits. Reddish till exposures seen in cuttings along the main Fochabers-Keith road to the east of the Forestry Commission plantations on Whiteash Hill and also around Keith are found up to 6.5 km (4 miles) east-south-east of the eastern edge of the O.R.S. outcrops shown on the geological map, providing a strong indication of former ice movement across the northern part of the sheet from west-north-west to east-south-east. South of a line through Dallas, lower Glen Latterach, Rothes and Hill of Towie, indications of glacial movement are much less obvious in the till, though there may be slight suggestions of south-west to north-east directional movement. The pattern of till deposition reflects the junction between two major subcomponents of the last major ice sheet to cover the area, and this is confirmed on the ground by the presence of well defined channels parallel to the line of junction in Teindland Forest, on the north-facing slopes of the Monaughty Ridge, Hill of Wangie, and at Blackhills and Romach Loch. To the north there are extensive fluvioglacial deposits, represented on Sheet 85 by sands and gravels around Rafford and Forres. To the south there is a belt of scattered moraines interspersed with large and small kettle-hole lochs over the high moor between Shenvault and the Dallas-Knockando Road.

Solifluction deposits, ranging from periglacial to post-Atlantic in age, are a common feature on lower hillslopes throughout the sheet. Where these materials do not differ significantly from till and drift deposits (as for example in the case of the Strichen Association) they are not specifically designated as soil parent materials on the key to the soil map. However, as on Sheet 94 (Tain), in areas where O.R.S. sediments are an important

component of the local till, some separation of solifluction deposits has proved necessary.

Eighty-seven soil series and one soil complex have been distinguished on the soil map and are distributed within the following Associations.

Association	*Parent Material*
Strichen	Till and drift derived from acid schists.
Durnhill	Till and drift derived from quartzite and quartz-schist.
Foudland	Till and drift derived from graphite-schist, slate and andalusite-schist.
Aberlour	Till and drift derived from acid schist, granulites and granite.
Countesswells	Till and drift derived from granite and granitic gneiss.
Tarves	Till and drift derived from acid schist and basic igneous rocks or hornblende-schist.
Insch	Till and drift derived from basic igneous rocks and hornblende-schist.
Leslie	Till and drift derived from ultrabasic rocks, mainly serpentine.
Tynet	Till and drift derived from M.O.R.S. conglomerates and sandstones.
Elgin	Till and drift derived from M. and U.O.R.S. sandstones, with some conglomerate locally.
Orton	Till and drift derived from M. and U.O.R.S. sandstones, conglomerates and acid schist.
Kindeace	Watersorted or morainic drift overlying till derived from M. and U.O.R.S. sediments.
Corby	Fluvioglacial and morainic gravels
Boyndie	Fluvioglacial sand
Knockando	Coarse textured stony moraine
Craigellachie	Compact fluvioglacial silt

In addition sixteen named series have been distinguished on alluvium, together with undifferentiated alluvium, peat-alluvium complex, solifluction deposits, blanket peat and mixed bottom land.

The Strichen Association is the most extensive group of soils on Sheet 85. Nine soil series and one complex have been distinguished. While complying with the general definition of derivation from acid schists, the soil parent material can show a limited range of variability reflecting the differences between the rocks of the Banffshire series which contain a fair proportion of slaty or shaly rocks, and the Central Highland Granulites which contain a high proportion of very acid schists close to quartzite in composition. On the eastern side the Strichen, Foudland, Durnhill and Tarves Associations are all present as components within a variable parent material mosaic, whilst on the west side the Strichen Association is dominant and widespread. The peaty podzol Gaerlie series is the most extensive and in association with blanket peat is the typical soil of the upland heather moors. There is a well developed surface layer of black mor humus and

peat up to 40 cm thick. This organic layer is strongly acid (pH 3·6 to 4·0) and overlies a very dark grey humose sandy loam A_2g horizon which is again acidic (pH 4·0 to 4·5) and has a subangular blocky structure. A thin iron pan is usually present below the A_2g sealing off the underlying strong brown to dark yellowish brown friable B_2 horizon from penetration by plant roots. At 40 to 50 cm below mineral ground surface a compact and indurated B_3 horizon is present which merges into a brown stony loamy coarse sand C horizon. The C horizon is still very acid (pH 4·5 to 5·2). The thin iron pan can be very irregular in outline and may be found in any position between the top of the B_2 horizon and the upper surface of the indurated layer, though these are the two more generally preferred positions. Within the peaty podzol zone there are many receiving sites around the lower hillslopes where peaty gley soils have developed. The poorly drained peaty gleys have been included in the Auquhollie series, and the very poorly drained peaty and humic gleys within the Hythie series. The two series are closely interrelated and there are many localities where precise distinction of the boundary between them is impracticable. The surface organic horizon may be very variable in thickness but usually includes a substantial layer of wet well humified peat with a transitional humus/mineral layer at the base. In the Hythie series olive grey or dark grey colours and massive structure characterize the B_2g horizon, and continue into the B_3g horizon where well preserved dead woody roots are often present. In the Auquhollie series dark greyish brown colours and weak prismatic or weak coarse angular to subangular blocky structure may be present in the B_2g. The B_3g horizon of the Auquhollie series closely resembles that of the Hythie series. Where drains have been installed structures gradually develop in the B_2g horizon of the Hythie series which are similar to those naturally present in the Auquhollie series and some diffuse ochreous mottling may develop in response to intermittent aeration of the B_2g horizon.

On hilltops above 490 m (1600 feet) there is a limited development of the subalpine podzol Kichanroy series on those sites where blanket peat is not present. The change from peaty podzol to subalpine podzol morphology, with increasing altitude, is associated with gradual elimination of the thin iron pan, which at first becomes soft and easily penetrated by plant roots, and then disappears as a recognizable feature. Similarly the indurated B_3 horizon, which is generally a feature of the peaty podzol profile, is either weakly developed or absent from the subalpine podzol. On the highest part of Creag an Tarmachain and on the south-western part of Ben Rinnes there is a limited development of alpine soils developed on schist which have been included in the Ealasaid series. The profile has a thin A_0 horizon underlain by a grey to black A_2 horizon 2 to 5 cm thick containing bleached sand grains. Below the A_2 horizon there is a black horizon 15 to 30 cm in thickness in which the stones and grit are stained with colloidal humus and the interstitial fine material is loose and friable. This has been described as the alpine A horizon and the less than 2 mm fraction may contain up to 15 per cent of organic matter when the soil parent material is derived from schist. Below the A horizons there is a transitional A/C horizon in which the colour variation from very dark brown above to brown below is matched by a

gradual fall in organic matter content. It is probable that in the north-east of Scotland the boundary between subalpine podzol and alpine soil marks the former upper limit of scrub pine forest.

Below 300 m (1000 feet), where most of the agricultural land has been developed, podzolic soils of the freely drained Strichen series and the imperfectly drained Obney series are more common, and local patches of freely drained brown forest soils have been included within the Fungarth series. Poorly drained soils are usually non-calcareous gleys of the Anniegathel series, though peaty gleys of the Auquhollie series may also be present.

In the semi-natural profile of the Strichen series there is a surface layer of litter and black mor humus 5 to 10 cm thick overlying a very dark grey A_2 horizon with prominent bleached sand grains. At the base of the A_2 there is usually some accumulation of very dark brown to black humus and below there is a dark yellowish brown friable B_2 horizon about 20 cm thick. This in turn is underlain by a brown to yellowish brown indurated B_3 horizon 20 to 45 cm thick. In the Fungarth series the A_2 horizon is dark reddish brown to dark brown with some bleached sand grains and is underlain by a very friable dark grey brown to dark brown A/B horizon 15 to 20 cm thick which merges into a dark yellowish brown friable B_2 horizon similar to that of the Strichen series. In both series the pH value of the surface humus layer is just over pH 4·0, whilst the range is pH 4·4 to 4·7 in the A_2 horizon and pH 5·2 to 5·6 in the C horizon. The carbon-nitrogen ratio is around 10 in the first mineral horizon of the Fungarth series and nearer 20 at the corresponding level in the Strichen series. After cultivation profiles of these two series are not readily distinguishable and, though it has been conventional to include all the cultivated freely drained soils within the Strichen series, it is quite probable that a proportion were formerly brown forest soils developed under birchwood, rather than podzols developed under pine woods and/or heather moor. Soils of the imperfectly drained Obney series are either podzols with gleyed B horizons morphologically related to the Strichen series or weakly developed non-calcareous gleys rather similar to the Anniegathel series. A large part of the Anniegathel series has been cultivated. Below the plough layer there is a strongly mottled ochreous, grey brown and grey B_2g horizon with well developed coarse prismatic structure down to about 50 cm. In the $B_3(g)$ horizon the mottling is similar but the structure becomes coarse subangular blocky and eventually massive in the C horizon below. The clay content of the less than 2 mm fraction in B_2g horizons is around 12 to 17 per cent in profiles from the eastern side of the sheet and 4 to 8 per cent in those from the western side. pH values in the range pH 5·5 to 6 have been recorded in samples from the cultivated layer of this series and values in the range pH 4·6 to 6·3 are commonly recorded in the C horizon. However, values in excess of pH 7·0 are occasionally recorded in the C horizon where limestone of the Banffshire series has been incorporated into the glacial till. Earthworms are generally present to depths of 40 to 60 cm in the cultivated soil, but appear to be restricted to the upper 25 cm when the limestone content of the till is significant.

Soils of the Durnhill Association are found mainly on ridgebacks and hilltops where the shallow drift or till is directly derived from quartzite rocks of the Banffshire series. The dominant Durnhill series is a peaty podzol with strong thin iron pan. A profile sited at about 290 m (950 feet) had about 10 cm of litter, fibrous black humus and black well decomposed mor humus over a stony dark grey loamy sand A_2 horizon about 11 cm thick which merged down into an A_2g horizon of comparable thickness. A strong thin iron pan was developed between the A_2g horizon and the yellow brown stony sandy loam B_2 horizon. The B_2 horizon was about 30 cm thick and underlain by an indurated stony loamy sand B_3 horizon of similar extent. At about 460 m (1500 feet) the thin iron pan becomes softer and is penetrated by roots and the indurated B_3 horizon is very weakly developed or absent. In the Durnhill series the pH value of the surface humus is about pH 4·0 rising to pH 4·8 to 5·5 in the C horizon. On the higher hills both the subalpine podzol Scraulac series and the alpine Corriehabbie series have been mapped. Development of the A horizon in alpine soils is closely related to parent material base status. In profiles of the Ealasaid series of the Strichen Association the A_2 horizon is minimal and the underlying black alpine A is the characteristic morphological feature. By contrast, in the Corriehabbie series there is a well defined dark grey A_2 horizon 6 to 10 cm thick overlying an attenuated black alpine A horizon with a humus content below 6 per cent in the less than 2 mm fraction. Poorly and very poorly drained peaty gleys of the Neuchry series and Balloch series are minor components of the upland soil pattern. North of Newmill and around the footslopes of Ben Aigan the Durnhill Association extends appreciably below the 260 m (850 foot) contour and podzolic soils of the freely drained Aigan series and the imperfectly drained Ferneybrae series have developed together with non-calcareous gleys of the Kilbady series. A freely drained humus iron podzol profile from the steep footslopes of Ben Aigan had about 23 cm of litter and black fibrous over a 21 cm dark brown (drying out grey) stony loamy sand A_2 horizon. At the base of the A_2 there was about 3 cm of black humose sandy loam underlain by a stony dark brown and yellow brown friable sandy loam B_2 horizon 25 to 35 cm thick. Below the B_2 horizon there was a yellow brown rather weakly cemented stony loamy sand B_3 horizon which merged gradually into a light yellow brown stony loamy sand C horizon. pH values ranged from below pH 4·0 in the surface humus to a little over pH 5·0 in the C horizon.

Soils of the Foudland Association are best developed in Glen Rinnes; elsewhere they have been mapped in discontinuous patches generally related to outcrops of the black graphitic schist from which the soil parent material is mostly derived. Seven series are represented on the map. The Suie series (peaty podzols), the Foudland series (freely drained podzols), the Mairlenden series (imperfectly drained podzols and weak non-calcareous gleys) and the Fisherford series (poorly drained non-calcareous gleys) are all of appreciable extent. The Ladylea series (subalpine podzols), the Drumardoch series (poorly drained peaty gleys) and the Shanquhar series (very poorly drained peaty gleys) are of limited local interest only. The presence of graphite-schist gives a unique " steel grey " appearance to the dark grey A_2

or A_2g horizons of the podzols and peaty podzols and the friable dark yellowish brown B_2 horizon has a characteristic fine sandy loam or silty loam texture. Indurated B_3 horizons are generally absent or rather weakly developed in podzolic soils of the Foudland Association. In podzols and peaty podzols the pH value of the surface humus layer is about pH 4·0, rising to about pH 5·0 in the C horizon.

In the area between Rothes, Archiestown, Dufftown and Ben Rinnes the Aberlour Association has been distinguished. The soil parent material is of a type intermediate in composition between that of the Strichen and Countesswells Associations. It is derived either from a mixture of granite and schist, or from granulites intruded by multiple granite veining as seen in the Blue Hills quarry near Aberlour. Six soil series have been distinguished. The dominant series are the Lynmore series (humus-iron podzols) and the Aberlour series (peaty podzols). Poorly drained peaty gleys and non-calcareous gleys of the Cantrydoune and Luig series are well developed in Elchies forest and around Archiestown, whilst imperfectly drained non-calcareous gleys of the Glaschoil series are one of the more important arable series in the Ruthrie-Kinermony area. Very poorly drained peaty gley soils of the Refouble series are of limited extent. A cultivated soil of the Lynmore series in the midslope position on a hill south of Aberlour had a dark brown sandy loam surface horizon 36 cm thick over a dark brown to brown friable B_2 horizon. Below 63 cm there was a moderately indurated sandy loam B_3 horizon, which merged down into a compact brown silty fine sandy loam C horizon. The Aberlour series is widespread on the gently sloping uplands north of Archiestown which have been extensively planted by the Forestry Commission. The soil profile at around 300 m (100 feet) has an organic surface horizon 20 to 35 cm thick made up of surface litter, fibrous very dark brown peat and a substantial basal layer of well decomposed black greasy peat. Under the A_0 horizon there is a dark grey to dark grey brown and black coarse sandy loam to loamy coarse sand A_2g horizon. At the base of the A_2g horizon there is a strong thin, rather irregular, iron pan with a well developed root mat on the upper surface. This iron pan may overlie a friable strong brown sandy loam B_2 horizon or may be formed directly upon the upper surface of a brown indurated B_3 horizon. Poorly and very poorly drained peaty gley soils tend to form in local hollows scattered over the moorland dominated by the Aberlour series. In the Cantraydoune series there is a surface layer of up to 25 cm of fibrous humus and peat underlain by a thin dark grey brown A_2g horizon which merges down into a 12 to 15 cm thick olive grey to olive sandy loam B_2g horizon. Below the B_2g there is a grey brown and olive sandy loam B_3g horizon with coarse prismatic structure which gradually merges into a massive brown to dark brown C horizon below 70 to 80 cm. In all the uncultivated soils pH values range from about pH 4·0 in the surface organic layers to slightly below pH 5·0 in the C horizon, with minimal values at or just above mineral ground surface. In the cultivated soils rather higher values, up to pH 5·8, have been recorded in the C horizon.

Soils of the Countesswells Association, developed on till or drift derived

from the local granite, are found on the high ground around the Aberlour Association. The principal localities are Ben Rinnes, the Convals and Hunt Hill, with minor outlying patches on Hill of Mulderie and at Keith. Arable soils are of very limited extent and confined to the Countesswells and Dess series. On the upland moors the Charr series is widespread and peaty podzols have developed on both till and semi-residual gritty granite drift. The profile at about 300 m (1000 feet) has a substantial surface layer or litter, fibrous humus and black greasy peat, over very dark grey brown and very dark grey A_2 and A_2g horizons. At the base of the A_2g horizon there is a strong thin iron pan which is usually found directly upon the upper surface of a brown to yellowish brown indurated coarse sandy loam B_3 horizon. The indurated layer may be up to 40 cm thick and merges into a brown loamy coarse sand C horizon. Higher up the hill the profile becomes more telescoped, the thin iron pan is soft and penetrated by roots and, where blanket peat has not developed, profile morphology gradually changes to that of the subalpine podzol Saighdeir series. In the Saighdeir series a thin variable black humus and mineral A_0 horizon overlies about 10 cm of black to very dark brown humose sandy loam with bleached granite grit. Below this humus A_2 horizon there is a very friable dark yellowish brown and very dark brown gritty sandy loam B_2 horizon underlain by a compact B_3 horizon penetrated by roots, which merges into a brown gritty sandy loam C horizon. Alpine soils of the Rinnes series are well developed only on the summit plateau of Ben Rinnes. At 760 m (2500 feet) there is a surface mosaic of bare ground interspersed with patches of wind-blasted *Calluna, Vaccinium* and mosses. The profile has a 7 cm surface layer of black humus speckled with pale brown bleached granite grit. Below this leached A_2 horizon there is a pavement-like layer of flat granite slabs with very friable black mineral humus material between and below. Stones and grit are stained black throughout this 23 cm thick alpine A horizon, and the organic matter content of the less than 2 mm fraction is about 13 per cent. Below the alpine A horizon there is a humus stained sandy loam A/C horizon 50 to 60 cm thick. The upper part is very dark brown in colour with about 3 per cent organic matter in the less than 2 mm fraction. The lower part is brown and the organic matter content less than 0·5 per cent. Roots penetrate to about 80 cm and the underlying solid granite rock is present at about 90 cm.

Soils developed on till or drift derived from basic and ultrabasic rocks with varying proportions of acid schist are of limited extent and confined to the south-east corner of the sheet. Fifteen series of the Tarves, Insch and Leslie Associations have been distinguished but few are of any appreciable extent and fewer still are agriculturally significant. Of the latter the freely and imperfectly drained soils of the Tarves and Thistlyhill series are the most important and constitute a fair proportion of the arable land along the valley sides of the Deveron between Bridgend and Invermarkie. In the Tarves series the dark brown sandy loam surface horizon is underlain by a brown to dark brown friable B_2 horizon 20 to 25 cm thick. Below the B_2 horizon there is an indurated B_3 horizon similar, if rather greyer, in colour and about 60 cm thick. The C horizon is usually atten-

uated with the underlying rock not far below. In the imperfectly drained Thistlyhill series the B_2(g) horizon is friable and comparable in thickness to that of the Tarves series, but is more greyish brown in colour with some fine ochreous mottling. The weakly indurated B_3(g) horizon is light yellowish brown with some distinct ochreous mottling and less than 30 cm thick. A distinctive feature of the cultivated soils of the Tarves Association is the relatively high level of total phosphorus.

Areas in which sedimentary rocks of Old Red Sandstone age make a significant contribution to the soil parent material are confined to the northern part of the sheet. The associations distinguished include the Tynet Association whose parent material is mostly derived from conglomerates, the Elgin Association developed where sandstone is the main component of the till, and the Orton Association which has been mapped where there is a mixed till derived from sedimentary rocks and schists. A large proportion of the soils of the Tynet Association are found on Whiteash Hill and Hill of Ordiequish. Freely drained podzols of the Tynet series dominate the lower slopes of Whiteash Hill, whilst peaty podzol of the Ordequish series are restricted to the hilltop and upper north-facing slopes. On Hill of Ordiequish the pattern is reversed and podzols are very largely restricted to limited areas on the lower slopes facing the Spey Valley. Imperfectly drained soils of the Aultash series, together with poorly drained non-calcareous gleys of the Whiteash series and peaty gleys of the Gow series, occupy small areas where catchment waters concentrate around streamheads and lower hillslopes. Soils of the Elgin Association are found west of the Spey and at Monaughty. Poorly drained peaty gley soils of the Uack series and imperfectly drained soils of the Rosebrae series, together with peaty podzols of the Teindland series, dominate the soil pattern on the high ground at Teindland and Brown Muir, whilst humus-iron podzols of the Elgin series are found on the lower slopes. Farther west at Monaughty the imperfectly drained Rosebrae series is dominant with the Elgin and Monaughty series present to a lesser extent.

The mixed till forming the parent material of the Orton Association is irregularly distributed around the southern and eastern edges of the Elgin and Tynet Associations between Glen of Rothes and Keith. It is also found on the higher slopes of the Monaughty ridge, on the south-west corner of Hill of Wangie and in scattered patches around Rafford. Semi-natural podzolic soils of the imperfectly drained Urchany series and the freely drained Phorp series, with peaty podzols of the Orton series and peaty gleys of the Brylach and Heldon series, have been distinguished. A considerable proportion of the soils are cultivated. The Phorp and Urchany series are ubiquitous throughout all arable areas, whilst non-calcareous gleys of the Romach series are especially extensive around Gow Moss. The cultivated Phorp series has a very dark brown sandy loam surface overlying a friable yellowish brown sandy loam B_2 horizon. Below the B_2 there is a yellowish brown to brown indurated sandy loam B_3 horizon, which gradually becomes more reddish brown with depth and merges into a compact reddish brown sandy loam C horizon about a metre below the surface. In the Romach series the surface horizon is a very dark grey sandy loam and the Bg

horizons are grey brown above becoming brown and reddish brown below with sandy loam texture, a coarse prismatic structure and ochreous mottling. The soils of the Urchany series are intermediate in character between those of the Phorp and Romach series.

The Corby and Boyndie Associations are found on the fluvioglacial terraces and moraines of the Spey-Avon valley system and to a lesser extent in the Lossie valley. Scattered moraines over the high moors west of the Knockando-Dallas road form impressive topographic features, but an extensive development of blanket peat has greatly reduced their pedological significance. A range of five series, from freely and imperfectly drained humus-iron podzols through non-calcareous gleys to very poorly drained peaty gleys with peaty podzols on the high moorland, has been mapped within each association. The freely drained Corby series developed on fluvioglacial and morainic gravels and the freely drained Boyndie series developed on fluvioglacial sand are the most agriculturally significant. Both soils are humus-iron podzols which may have either a friable or a cemented dark brown and dark yellow brown B_2 horizon. The cemented B_2 horizon (or "Moray pan") does not always prevent the penetration of roots and does not seriously impede vertical drainage. The B_2 horizon merges down into a yellowish brown somewhat cemented B_3 horizon.

Various coarse textured morainic deposits which have a generally higher clay content than is acceptable in the Corby Association have been grouped together as the parent material of the Knockando Association. The dominant soil series developed are the Knockando series (freely drained podzols) and the Avon series (peaty podzols). In profile morphology these soils closely resemble the Corby and Tarbothill series.

Soils of the Craigellachie Association which are developed on compact fluvioglacial silts occur in rather discontinuous patches on both sides of the Spey Valley between Knockando and Craigellachie. This is an area where there are fluvioglacial and morainic deposits of very variable composition and the Boyndie, Corby, Knockando, Craigellachie and Aberlour Associations are interdigitated in a rather complex pattern. As well as having an irregular surface distribution pattern fluvioglacial sand and silt are frequently interstratified. There is also a variable interrelation between compact finely laminated silt, silt with stones and boulders, and till of the Aberlour Association. It seems probable that some part of the silts may have been deposited at a time when the Spey valley contained "dead ice" and that subsequent slow melting of buried stagnant ice masses has caused local slumping and flowing of the overlying deposits. There is a general west to east variation in the textural composition of the parent material of the Craigellachie Association. Silt textures are common in the deposits south of Knockando, silt loams are found around Carron and Kinermony, and silt clay and clay south of Craigellachie. This trend does not exclude some textural variation within individual profiles and takes no account of thin bands and lenses of sandy or gravelly material which are not uncommon within this kind of deposit. The greater part of this association occurs below 210 m (700 feet) and the soils are extensively cultivated. The dominant series are the imperfectly drained Craigellachie series and the poorly

drained Drumfurrich series. The Craigellachie series includes podzolic soils with gleyed B and C horizons and weak non-calcareous gleys. A profiile from the north side of the Spey had a dark greyish brown surface horizon overlying a brown to dark brown silty fine sandy loam B_2 horizon with sub-angular blocky structure and firm consistency. Below the B_2 horizon there was a silt loam B_3(g) horizon with coarse prismatic structure, firm consistency, and some ochreous mottling, merging down into massive compact finely laminated silt loam. South of the Spey near Craigellachie silty clay textures predominate and coarse prismatic structure with some ochreous mottling is present in both B_2(g) and B_3(g) horizons. The Drumfurrich series has developed on silt south of Knockando and silty clay south of Craigellachie. The texture of the plough layer varies from fine sandy loam in the west to silty clay loam in the east. The Bg horizons are grey or olive grey with coarse prismatic structure. The C horizon is grey or olive grey with ochreous " pipe mottling " around old root channels and the structure is massive and compact.

Arable land on Sheet 85 is largely restricted to the main valleys and the Moray Coastal zone and it therefore comes as no surprise that about two-thirds of the area of the Land Use Capability map is included within classes 5, 6 and 7 and reckoned to be unsuitable for cultivation. Class 1 land is not present, and class 2 land is of negligible extent and the bulk of the cultivated land is almost equally split between classes 3 and 4. About one third of the land rated unsuitable for cultivation is included in class 5 and therefore potentially capable of some degree of improvement for grazing purposes. About 5 per cent of the total area is included in class 7, which includes high mountain tops, bare rock, mixed bottom land, and built-up areas. It will be appreciated that this classification is not necessarily applicable to forestry. For example, base-rich soils on steep mixed bottom land may be totally unsuitable for agriculture, but well adapted to the growth requirements of a tree crop.

Ninety per cent of the semi-natural soils so far analysed have pH values below 5·0 in the surface mineral horizon and in the remainder (which are developed on parent materials derived from serpentine and ultrabasic rocks) values do not exceed pH 6·0. About 65 per cent lie within the range pH 4·0 - 4·6 and a similar proportion of the cultivated soils have S horizon values in the range pH 6·0 - 6·6. This differential can only be maintained by the regular application of lime, and the pH value of the S horizon in old grassland can, in the absence of liming, revert to the semi-natural level within 20 years. The high priority accorded to liming is confirmed when the exchangeable cation levels are reviewed. About 54 per cent of the soils have " high " levels of calcium (>8·0 me 100 g) and about 42 per cent have " medium " levels (8·0 - 3·0 me 100 g). For magnesium 88 per cent of the soils are in the medium bracket (5·0 - 0·3 me 100 g) and for potassium 79 per cent lie in the medium range (1·0 - 0·1 me 100 g). Total phosphorus values have been generally maintained at levels comparable with magnesium and potassium with 80 per cent of soils in the medium bracket (300 - 100 mg 100 g). Very few of the soils examined had low levels of either lime or phosphorus.

LIBRARY

The library service received a setback in December with the premature death of Mrs Noble and it was not until April that the library was again fully staffed. The routine procedures were maintained, however, and, in the later part of the year, the clearance of the annex, to take older stock from the main library, progressed satisfactorily.

Although the service is maintained primarily for members of staff, extensive use was made of it by visiting research workers and by students and staff from nearby establishments. Queries and loans were also dealt with by letter and telephone.

349 books were added to stock and, despite rising subscriptions, it was not necessary to cancel any journal titles. However, no new journals were purchased. During the year a " Survey of Journal Usage " was carried out in order to plan for possible changes in 1977.

Inter-library loans continued to be an important aspect of the library service with 910 items being borrowed from external sources; 503 of these were from the British Library Lending Division. 146 items were lent to other libraries in response to 207 requests.

Two " Lists of Available Publications " were distributed to addresses throughout the world. The response was high with 4041 reprints being requested. Over 1000 reprints were also sent out as a result of casual requests. Anyone wishing to receive a copy of the lists should apply to the librarian.

In March the library purchased a portable microfiche reader; a Scottish Instruments Lensman Mark IV.

In June Mrs Alcock attended a meeting of ARC librarians, in London, primarily to discuss the report of the ARC Working Party on Library and Informaton Services. In September she took part in an experimental course on " On-line Techniques for Information Retrieval " at Robert Gordon's Institute of Technology, Aberdeen. This proved of interest and use to several members of staff who furnished her with literature queries.

APPENDIX

FIRST

T. B. MACAULAY LECTURE

25th NOVEMBER, 1976

AMATOLA HOTEL, ABERDEEN

by

SIR WILLIAM HENDERSON, DSc, DVMS, FRCVS, FRS

Chairman:

Professor T. C. Phemister, MSc, PhD, DSc, FRSE

FIRST T. B. MACAULAY LECTURE
Aberdeen, 25th November, 1976

SCIENCE POLICY FOR AGRICULTURE

SIR WILLIAM HENDERSON, FRCVS, FRS
Agricultural Research Council, London, W1N 6DT

In June 1928, a letter was received in the then Department of Agriculture for Scotland from the President of the Sun Life Insurance Company of Canada. This was Thomas Bassett Macaulay inviting the co-operation of the Department in furthering his proposals for the improvement of the agriculture of the island of Lewis. His father had emigrated from there to Canada as a young man. Although Mr Macaulay's original intention had been to set up an experimental farm on Lewis, he was persuaded to widen his scheme to include the establishment of an experimental station on the mainland for the study of soils and soil-plant relationships. At that time the significant work on soil chemistry was being done at Rothamsted, Bangor, Edinburgh and Aberdeen. It was natural, therefore, that the Department of Agriculture should seek the advice of Professor Hendrick in Aberdeen and of Dr Ogg in Edinburgh. It was thus that Sir William Ogg was asked to find a suitable location where the generous Macaulay benefaction of £27,000 could best be invested. So came to be chosen Craigiebuckler House as the site for the Macaulay Institute for Soil Research where work started in 1930 under Dr W. G. Ogg as first Director. In the meantime the Agricultural Research Council was established in 1931 and a Visiting Group was sent to the Institute in 1934. The Group reported that the work of the Institute was good, but that it was hampered by want of funds. Owing to the financial crisis, Mr Macaulay had been unable to help as much as he had intended, a debt had accumulated, and both capital requirements and maintenance needs were above present resources. The Institute survived then as it will now and I am confident that the staff will perform as creditably as their predecessors when they meet the Council's Visiting Group which is coming to see them next year.

In searching for these historical references, I came across another item which I cannot resist quoting from the 1933/1935 Report of the Agricultural Research Council: "As a result of recommendations made by a Sub-Committee appointed to examine the present position of spectrographic research on soils, the Council made a grant to the Macaulay Institute in 1935 of £850 for the purchase of a photometer flame spectrograph, and accessories, and the salary for one year of Dr R. L. Mitchell, who was selected to study methods of spectrographic analysis of soils." Thus did the fourth and recently retired Director of the Institute come on to the payroll and thus were laid the foundations of one of the foremost spectrochemical laboratories in the world. It is interesting to mention in passing that the latest refinement in the way of equipment, the new AEI MS702R spark-source mass-spectrometer, cost the Department of Agriculture and Fisheries for Scotland the sum of £60,000. Thus was the Institute set on

its course and we have seen its reputation grow and be enhanced under the leadership of Ogg, McArthur, Stewart and Mitchell and now to be in the safe hands of Professor West. His invaluable contributions in his field of chemical analysis and his appreciation of the need to study soils in the context of biology provide great confidence for the future. It was, therefore, with great pleasure that I received through Professor West the invitation of the Council of Management of the Institute to deliver this first T. B. Macaulay Lecture. It is in tribute to your Founder that I now address you on "Science Policy for Agriculture."

I wish to refer specifically to science for agriculture within the scientific remit of the Agricultural Research Council, namely, within the agricultural research service. This service consists of the 8 Scottish Agricultural Research Institutes grant-aided by the Department of Agriculture and Fisheries for Scotland, the 14 Institutes in England and Wales grant-aided by the A.R.C., the Council's 8 Institutes and 9 Units, all 39 establishments being under the scientific oversight of the Council. Since 1973 the ARC's funds have been partitioned between the Science Budget of the Department of Education and Science and the Research and Development vote of the Ministry of Agriculture, Fisheries and Food as a result of Government's implementation of the customer/contractor procedure for commissioning research.

Many of you know how in 1972/73 the ARC, together with MAFF and DAFS, decided to establish under their joint sponsorship the Joint Consultative Organisation for the assessment of priorities for research and development in agriculture and food. There are, therefore, the ARC, the two agricultural departments, the JCO, and the Institutes and Units of the agricultural research service all involved to a greater or lesser extent with the assessment of priorities, the planning of programmes, the allocation of resources and the conducting of research, but it is the Council that is vested with the overall responsibility for advancing scientific knowledge relevant to agriculture.

It is necessary at this stage to refer to the other Research Councils and to the Advisory Board for the Research Councils. The Medical Research Council was established in 1913, the ARC in 1931 and for many years these two Research Councils, together with the Department for Scientific and Industrial Research, came directly under the Privy Council. The Science and Technology Act, 1965, transferred to the Secretary of State for Education and Science the functions hitherto exercised by the Privy Council with respect to the MRC and the ARC, the DSIR disappeared and the Science, Natural Environment and Social Sciences Research Councils were established. The Secretary of State is responsible for the finances of the Research Councils and hence for the allocation of resources between them. In the exercise of this responsibility she is advised by the Advisory Board for the Research Councils. This Board was established in 1972 in replacement of the Council for Scientific Policy. This change in the Secretary of State's advisory body was part of Government's implementation of the Rothschild proposals which identified the customers and the contractors. The membership of the ABRC is central to my theme in that it consists of the Chief

Scientists of the Customer Departments and the Heads of the Research Councils tempered by a similar sized group of independent members. I became a member of this Board in 1972 when the Science Budget had an annual growth of 4·2 per cent and the ARC received 15·6 per cent of the total. Since then, annual growth has disappeared and because of the transfer of funds to the Ministry of Agriculture, Fisheries and Food, the ARC's share of the Science Budget has dropped to 8 per cent. It has been possible, nevertheless, during the last few years to preserve a reasonable place for agricultural research, but only at the expense of the "big" science supported by the Science Research Council. The application of the customer/contractor principle created a divisive situation, the worse features of which have been successfully surmounted in the ARC/MAFF relationship, but the present period of severe financial stringency has created a new divisive situation between the Research Councils. This has accentuated the difficulties of classifying research and of determining scientific policies. In the Rothschild Report two classifications of research were emphasised, namely, applied R & D that "must be done on a customer/contractor basis" and basic research. Fifty-six per cent of the ARC's research has been classified as "applied" in that sense by the transfer of that proportion of its funds to the customer department. When, therefore, the ABRC is attempting to reconcile the conflicting claims for, say, nuclear physics compared with plant pathology, those supporting nuclear physics want to be very sure that our proposals for plant pathology are sufficiently basic to warrant funding from the Science Vote. This attitude can be clearly understood when it is realised that with a static or diminishing budget, support in one area means a cut in another.

All sectoral research, no matter how basic it may be, is conducted in an applied ambience and I have, for example, detected a tendency for people to speak of scientific research and agricultural research. Although I always feel bound to refute this implication that agricultural research is not scientific, there are, perhaps, some current advantages in it not being put in the same classification as astronomy, space science and nuclear physics. You will, nevertheless, understand my choice of title of my lecture, "Science Policy for Agriculture."

In spite of Lord Rothschild's rejection of the "Haldane Principle" as being no longer relevant to the contemporary scene and without analysing the precepts of the "Principle," there is no doubt that the MRC and the ARC saw in their responsibility to the Privy Council a buffer between short-term Departmental priorities and long-term scientific objectives. This buffer was finally removed in April 1973, as the pressures on meeting the requirements of the customer department are a negation of much that I still respect in the "Haldane Principle."

The arrangements in Scotland are different in that the 8 Scottish Agricultural Research Institutes are funded solely by the Department of Agriculture, adopting the rôle of both customer and contractor. There are potential difficulties in this arrangement, but this aspect must not be exaggerated because the responsibility for the science of the Department's research programme belongs to the Agricultural Research Council, in the same way that

the science used in the research commissioned by MAFF is the responsibility of the Council. It is appropriate in this connexion to stress that the contribution from the Scottish Institutes is not solely for Scotland but that their programmes, although planned in the context of Scottish needs and conditions, are an invaluable part of the total British effort in agricultural science.

There is no dispute about the quality of the science required, it must be good science fostered in centres of excellence, it must also be relevant and responsive to the problems of society and the environment. On the timescale of most agricultural research, this means in the case of new work the problems of society and the environment of up to 10 to 20 years from now.

What success can be attributed to agricultural research in the past? The achievements of British farming are evident enough. In the last two decades agricultural production has increased by 75 per cent with a labour force that has decreased to half its former size. This reduction in labour has been achieved by a great increase in capital investment in mechanisation and buildings. Cereal production increased by 50 per cent during this period, potato production by 30 per cent with the total consumer demand being met from a 40 per cent reduction in acreage. The current peak production of milk has been achieved by three-quarters coming from increased yields and only one-quarter from increase of the national herd. This story can be repeated for most agricultural and horticultural commodities. Our herds and flocks have never been healthier nor more efficiently fed. I need not tell this audience that the stewardship of our heritage, the soil, has steadily improved as our knowledge and understanding of it has been progressively expanded. There have been many contributors to this success story, the manufacturers of agricultural machinery and equipment, the producers of fertilisers, herbicides and pesticides, the feed compounders, the seed merchants, those of all the other supporting industries, the farming community, the staffs of the agricultural departments, both advisory, executive and administrative, the teachers in the Universities and Colleges and the members of the research service. It would be invidious to attempt to apportion credit, but I would make the point that much of the new technologies that have been developed were built upon the results of scientific research. It is my claim that the Agricultural Research Council's policy of delegating as much responsibility as possible to the Directors of its Institutes and Units has contributed greatly to the excellence of this research effort. Will the very great changes of the last three years permit the research service to continue to flourish? I am convinced that whatever further changes may be in store we must preserve the following tenets:

1. An exclusive management responsibility for the contractor in implementing the customer/contractor procedure.
2. The retention of large commissions with a broad description of their objectives and sub-objectives.
3. The retention of the maximum degree of autonomy and independence of Institutes and Units consistent with the recognised need for more central control.

4. The maintenance of the highest standards in the recruitment of staff and the provision of adequate opportunities for the development of their talents and capabilities.
5. The maintenance of the best balance in the development of resources in a contracting financial situation so as to retain an elite staff, well accommodated, well equipped and well supported.

These tenets are essential in current circumstances for the successful conducting of our necessarily mixed programme of applied and basic, short-term and long-term research. The results of this programme should continue to provide the options for agriculture in whatever social, economic and political situations that the country may find itself in the next two decades.

I believe it is not too difficult to forecast some of the predominant features of our society in the 1980s and 1990s that have relevance as guidelines in the development of agricultural research policy. As far as agriculture is concerned, these projections must be made in a context of evolution not devolution and it is less easy to forecast the extent to which Europe will have become a true community. If we are successful in our progress towards this goal we may, perhaps, expect to find considerable changes in the pattern of British agriculture.

This could result from the development of the Common Agricultural Policy towards the concentration of commodity production into the most favourable region for each. There may well be changes in the structure of European agriculture because it is difficult to see how essential high levels of production can be achieved without drastic changes in the sociology of European farming. I see no reason, however, why this should result in complementary changes in our programme of research. One of our biggest contributions to the welfare of the EEC is and can continue to be our leadership in agricultural research. The results of this research are today of benefit far beyond our British boundaries. Through our participation in the EEC co-ordinated programmes of agricultural research, our influence is already extending into the rest of Europe within an EEC framework. This expanded scene is certainly going to be one in which there are more people to feed with less land available to agriculture. International trade in agricultural products will be more keenly contested and we may be energy-starved compared with our current use of this resource. Our aims must surely be to increase the productivity per unit area of agricultural land, to make much greater use of our agricultural production by reducing waste, by the processing of currently wasted components into usable products and to achieve all this with economy in energy-demanding inputs. It is already generally accepted that there would be a diminishing return in the use of additional energy inputs. The major source of improvement of agricultural output per unit area must be the discovery and implementation of new technology. Technological improvement, much of it made possible by the results of scientific research, led, as I have already noted, to many of the advances of the last two decades, but it seems unlikely that these improvements can be continued much further into the future. New forms of

technology are required and it is the pursuit of these that must be the science policy for agriculture.

The development of a policy must start with an assessment of priorities and the criteria to be used for the long-term view are not the same as those for the short-term view. The commodity Boards and Committees of the JCO have done an excellent job in assessing the shorter term priorities which has amounted, in large measure, to a corroboration of the appropriateness of the current research programme. The crucial questions that also require to be answered refer to the identification of the areas of science in which research may lead to the new technologies. This is a responsibility of the Agricultural Research Council, in the execution of which it is very greatly dependent upon the contributions of the scientists in the Institutes and Units. Up until very recently this evolutionary process could be accommodated within the generous financial support that was available for agricultural research. The position is very different today and for that reason specific priorities have to be identified into which resources must be redeployed if a greater effort is to be mounted. The ARC has established a Priorities Working Party for this purpose into which material is fed from a variety of sources.

This is not the occasion on which to discuss the growing points of research in any detail, but I am optimistic that we shall see major advances in the following fields:

Animal production

The selection of superior stock both for production and for disease resistance.

A closer integration of biochemistry and immunology in disease prevention and control.

A greater processing of animal products resulting in their less wasteful use.

A greater reliance on animal feed not directly consumable by man.

Crop production

The development of plant varieties meeting more closely the user's specification.

The development of plant varieties making more efficient use of available solar radiation.

The greater development of natural product substances for pest and disease control.

The greater use of biological control of pests and disease.

A greater understanding of the plant/soil relationship for maximum production consistent with the preservation of soil structure and quality.

General

The complementary development of agricultural machinery, equipment, buildings, manufacturing, processing and distributive services for exploitation of research and development successes.

I referred earlier to the tenets which I considered it necessary to preserve in today's changing scene. I suggested that we must retain the maximum degree of autonomy and independence of Institutes and Units consistent with the recognised need for more central control. The customer/contractor situation, the dependence upon commissions for the funding of two-thirds of the programme of the agricultural research service, the current financial constriction and the progress towards industrial democracy demand more central control. This is, possibly, the change of the greatest significance that is taking place. I don't contest this presumptively, but it is essential to strike the correct balance between central control and peripheral autonomy. Good science requires freedom, so the constraints that stem largely from the present devotion to accountability must be contained. It is our privilege to be contributing to the sciences which must be in the forefront of the technologies required for survival. This is a heavy responsibility, but it is its recognition and acceptance that accounts for so much of the success of agricultural research.

PUBLICATIONS

(A) *Published*

1. Thermal analysis. By R. C. Mackenzie. (pp. 389-420 of *Physicochemical Methods of Mineral Analysis.* Edited by A. W. Nicol. London: Plenum Press, 1975). No reprints.

   A review is given of some thermoanalytical methods used in mineralogical studies with special reference to instrumentation, experimental technique and applications. The value of simultaneous determinations and the necessity for use of complementary methods are also noted.

2. Influence of adsorbed phosphate on the dehydroxylation of synthetic goethite. By E. Paterson and R. Swaffield. (pp. 323-324 of *Proc. 1st Europ. Symp. Thermal Analysis, 1976.* Edited by D. Dollimore. London: Heyden, 1976). No reprints.

   The adsorption of phosphate on synthetic goethite significantly alters the shape of the dehydroxylation peak on the differential thermal analysis (DTA) curve. From this and other observations it would appear that phosphate adsorption and the consequent alteration of the surface structure of goethite has a considerable effect on the course of the dehydroxylation reaction.

3. The crystal structure of aluminium iodate nitrate hexahydrate. By P. D. Cradwick and A. S. de Endredy. (*J. Chem. Soc., Dalton Trans.* (19), 1926-1929, 1975). The crystal structure of aluminium iodate nitrate has been determined to establish whether the compound crystallizes as a mixed anion salt, $Al(IO_3)_2NO_3.6H_2O$ or a double salt, $Al(NO_3)_3.2Al(IO_3)_3.18H_2O$, as the chemical composition is identical for both. This compound is of interest as it crystallizes from a mixture of anions and the behaviour of the aluminium ion under these conditions may be relevant to aluminosilicate formation under natural conditions. The crystal structure showed that the compound did not exist as a double salt, and that the aluminium ion is present as the hexa-aquo cation, $Al(H_2O)_4^{3+}$.

4. Scanning electron microscope studies of a surface water gley. By W. J. McHardy and A. C. Birnie. (*J. Soil Sci.*, **26**, 427-431, 1975).

   Study of a Scottish poorly-drained soil by scanning electron microscopy and electron probe microanalysis has shown that manganese stains have a characteristic sponge-like appearance and that completely gleyed material has a fine, smooth texture in which individual clay particles are not visible. In material unweathered during soil formation, individual clay platelets can be clearly observed. The features observed are interpreted in terms of soil formational processes.

5. Ultrastructure and chemical composition of spines in Mucorales. By D. Jones, W. J. McHardy and M. J. Wilson. (*Trans. Br. Mycol. Soc.*, **66**, 153-157, 1976). Certain soil fungi are characterized by possessing spine-like projections on their spores and on the membranes associated with the spore-bearing structures. By employing a combination of techniques which included scanning electron microscopy, electron probe microanalysis, X-ray powder diffraction and infrared spectroscopy, more precise chemical information than has hitherto been available has been obtained on the spines.

6. The crystal structure of a trinuclear dinitrogen-bridged complex: Di-μ-dinitrogen -tetrachlorobis [chlorotetrakis (dimethylphenylphosphine)-rhenio] molybdenum-dichloromethane (1/1). By P. D. Cradwick. (*J. Chem. Soc. Dalton Trans.*, (19), 1934-1936, 1976).

   Study of the chemistry of nitrogen fixation is of fundamental importance to agriculture as an understanding of the processes involved could lead to utilization of atmospheric nitrogen either directly by the plant or through the soil. Structural studies of chemical models incorporating molecular nitrogen are important for establishing the degree of weakening of the N_2 bond. The present work describes in detail the structure of one such model compound.

7. Exchange properties and mineralogy of some soils derived from lavas of Lower Old Red Sandstone age: I Exchangeable cations. By M. J. Wilson and J. Logan. (*Geoderma*, **15**, 273-288, 1976).

   The cation-exchange properties of three freely drained and three imperfectly drained brown forest soils developed on volcanic parent material in east-central Scotland have been investigated. Examination of the clay, silt, fine sand and coarse sand fractions have shown that the non-clay fractions possess an appreciable cation-exchange capacity contributing proportionately more to the cation-exchange capacity of the total soil than does the clay. Sand and silt fractions are the main sources of exchangeable calcium and magnesium in the majority of these soils whereas most of the exchangeable potassium is associated with the clay fractions.

8. Exchange properties and mineralogy of some soils derived from lavas of Lower Old Red Sandstone age: II Mineralogy. By M. J. Wilson. (*Geoderma*, **15**, 289-304, 1976).

   The unusual cation-exchange characteristics of the soils described in Part I are closely related to mineralogy. The most important minerals in this respect are saponite (a swelling magnesium-rich mineral) and plagioclase felspar (calcium aluminium silicate). Saponite is responsible for the high cation-exchange capacity of the non-clay fractions as well as being a primary source of exchangeable magnesium. Exchangeable calcium is associated with the weathering of plagioclase felspar. Exchangeable potassium, which is concentrated in the clay fraction, cannot be associated with any particular clay mineral.

9. Nickeloan pyroaurite from Leslie, Aberdeenshire. By M. J. Wilson, P. D. Cradwick, M. L. Berrow, W. J. McHardy and J. D. Russell. (*Mineralog. Mag.*, **40**, 447-451, 1976).

   Nickel toxicity in plants growing on serpentinite-derived soils is often a serious problem. One possible source of readily available nickel is a nickel-bearing carbonate mineral which has been found in a serpentinite rock near the village of Leslie, Aberdeenshire, and which has been characterized by a variety of techniques. After the serpentinite is crushed to particles less than 2 mm in size, 70-80 per cent of the total nickel is soluble in acidic ammonium acetate (pH 4·5) and dilute acetic acid indicating that this mineral would be unstable in acid soils.

10 A Mössbauer study of the weathering of hornblende. By B. A. Goodman and M. J. Wilson. (*Clay Minerals*, **11**, 153-163, 1976).

   The behaviour of iron in the natural weathering of a hornblende has been investigated using the Mössbauer effect. Lamellar intergrowths of an iron-rich phase which weathers preferentially have a similar distribution of iron to the bulk hornblende. The proportion of ferric iron does not increase as a result of weathering and iron appears to be lost preferentially from sites in which it is co-ordinated to hydroxyl groups.

11. Occurrence of leucophosphite in a soil from Elephant Island, British Antarctic Territory. By M. J. Wilson and D. C. Bain. (*Am. Miner.*, **61**, 1027-1028, 1976). Leucophosphite, an unusual phosphate mineral containing iron, aluminium, potassium and ammonium, has been found as a major constituent in a soil profile on Elephant Island in British Antarctic Territory. The mineral originated through alteration of layer silicate minerals by ammonium phosphate solutions from guano, thus lending some support to the suggestion that similar phosphate minerals could occur in soils as the end products of phosphate fixation.

12. A titanium-rich soil clay. By D. C. Bain. (*J. Soil Sci.*, **27**, 68-70, 1976).

   A peaty podzol developed on glacial drift derived from chlorite-schists near Loch Awe, Argyllshire, contains up to 25 per cent titanium dioxide in the clay fractions after removal of organic matter and free iron oxides. This titanium is present almost entirely as cryptocrystalline anatase which has probably formed as result of the weathering of sphene in the soil.

13. The reaction of fluoride with soils and soil minerals. By K. W. Perrott, B. F. L. Smith and R. H. E. Inkson. (*J. Soil Sci.*, **27**, 58-67, 1976).

Sodium fluoride solutions release much greater quantities of hydroxyl ions from non-crystalline inorganic materials than from highly-crystalline minerals. A procedure has been devised for the estimation of relative amounts of non-crystalline inorganic material in soils and statistical analysis shows that results obtained for a range of Scottish soils correlate well with the amounts of alumina extracted by 5 per cent sodium carbonate solution at room temperature. The procedure is not suitable for surface soils, because of interference by organic matter, or for carbonate-containing soils unless carbonate is first removed.

14. Effect of pH on the reaction of sodium fluoride with hydroxides of silicon, aluminium and iron and with poorly-ordered aluminosilicates. By K. W. Perrott, B. F. L. Smith and B. D. Mitchell. (*J. Soil Sci.*, **27**, 348-356, 1976).

Non-crystalline inorganic gel systems common in Scottish soil clays react with fluoride ions releasing hydroxyl ions into solution. At pH values above 7·6 only hydroxyl ions associated with the aluminous component of aluminosilicate gels react and above pH 8 the contribution of hydrous ferric oxide gels becomes small. Measurement of hydroxyl release at high pH values can, therefore, be used to assess the amount of reactive hydroxyl groups associated with alumina and this, in turn, is related to phosphate sorption capacity.

15. A pyrolysis-gas chromatography method for discrimination of soil humus types. By J. M. Bracewell and G. W. Robertson. (*J. Soil Sci.*, **27**, 196-205, 1976).

Certain types of organic matter in surface soils can be readily distinguished by gas chromatographic examination of the products of very rapid pyrolysis. The identity and probable origin of the products and the changes with depth in the profile are discussed.

16. Pyrolysis-gas chromatography studies on a climosequence of soils in tussock grasslands, New Zealand. By J. M. Bracewell, G. W. Robertson and K. R. Tate. (*Geoderma*, **15**, 209-215, 1976).

The nature of the organic matter in the surface horizons of seven New Zealand soils under tussock grasslands has been shown, by pyrolysis-gas chromatography of the whole soils, to be strongly influenced by climate. Similarities with the mull/mor humus sequence in Scottish soils are noted.

17. Is maleic hydrazide a pyramidine or purine analogue? By P. D. Cradwick. (*Nature, Lond.*, **258**, 774, 1975).

Maleic hydrazide is widely used in agriculture as a growth inhibitor. Its crystal structure, as determined by X-ray diffraction, provides information that may have relevance to its mode of action.

18. Crystal structure of the growth inhibitor, "maleic hydrazide" (1,2 Dihydropyridazine-3, 6-dione). By P. D. Cradwick. (*J. Chem. Soc., Perkin Trans. II*, (12), 1386-1389, 1976).

Because of its close structural similarity to the pyrimidine base uracil, the replacement of uracil in the nucleic acid structure has been postulated as the mode of action of the growth inhibitor maleic hydrazide. Analysis of its crystal structure suggests that it could also replace the purine bases.

19. Slownik torfoznawczy Niemiecko- Polsko- Angielsko- Rosyjski (German- Polish- English- Russian glossary for bog and peat). By W. Bick, R. A. Robertson, R. Schneider (Hannover, Germany), S. Schneider (Hannover, Germany) and P. Ilnicki (Poznán, Poland) (Warsaw: Panst. Wydawn. Rolnicze i Lesne, 1976).

Scientific and technical terms relating to peat and bog research and to the related fields of agriculture, horticulture, forestry, hydrology and balneology are listed as in the previous trilingual glossary (Torfforschung GmbH, Bad Zwischenahn, 1973). The Polish edition features additional entries and indexes in Polish, English and Russian, retaining the alphabetical order of the German terms in the main text. The publication contains 2277 terms and a reference list of literature consulted in the compilation of this work.

20. Evaluation of peatland sites according to their physical and chemical characteristics. By H. G. Miller, R. A. Robertson and B. L. Williams. (pp. 165-175 of *Proc N.E.R.C. Symp. Peatland Forestry, Edinburgh 1968*. Printed 1973, published 1975). No reprints.

For afforestation, the value of subdividing blanket peat into narrower site types has sometimes been questioned, particularly when it results in a mosaic of species. In order to ascertain whether the scheme of subdivision practised by the Forestry Commission in northern Scotland reflects variation in soil nutrient content, a series of profiles, representative of site types within an area of blanket bog in Sutherland, were sampled on a volume basis. These site types, which had been selected on the basis of vegetation and topography, were found, with certain exceptions, to be fairly closely related to nutrient content. Two trends could be detected, these apparently being related to flushing on the one hand and to erosion on the other; both result in an increased weight of dry peat per unit volume. This was the predominant factor controlling nutrient content but in addition the flushed types exhibited high concentrations of nitrogen, phosphorus and potassium whereas the eroded types were high in calcium and magnesium. Differences between sites were apparent both in the top 15 cm of peat and over the entire depth of profile sampled (52 cm) and could be related to variations in the relative proportions of the main components of the vegetation.

21. Effect of water table height on growth of *Pinus contorta* on deep peat. By R. Boggie and H. G. Miller. (pp. 93-101 of *Proc. N.E.R.C. Symp. Peatland Forestry, Edinburgh 1968*. Printed 1973, published 1975). No reprints.

    An experiment, located in Inverness-shire, is described in which *P. contorta* has been grown on deep peat in plots where water table levels have been artificially maintained at depths ranging from 0 to 33 cm from the surface. However, moisture contents of peat samples taken from different depths showed remarkably little difference between treatments and it is suggested, therefore, that improved growth with increasing depth of water table was the result of movement of moisture allowing greater penetration of oxygenated water after rain, better distribution of applied nutrients and the removal of toxic substances.

22. Physical and chemical factors influencing the cation-exchange capacity of peat under field conditions. By B. L. Williams. (pp. 177-185 of *Proc. N.E.R.C. Symp. Peatland Forestry, Edinburgh 1968*. Printed 1973, published 1975). No reprints. A study of some of the factors influencing the characteristic cation-exchange behaviour of peat is described. The number of exchange sites depends on the pH of the soil solution, and the concentration of these sites per unit volume in wet peat is determined largely by the moisture content. At pH values corresponding to those observed in the field, only a relatively small proportion of the exchange sites enter into the cation-exchange reaction. A comparison of the concentrations of exchangeable cations in different peatland types illustrates the influence exerted by topography, which controls the movement of mineral-rich ground-water, the moisture content of the peat and the extent to which the peat is subject to erosion.

23. Physical and chemical properties of peat. By V. Puustjarvi (Helsinki, Finland) and R. A. Robertson. (pp. 23-83 of *Peat in horticulture*. Edited by D. W. Robinson. London: Academic Press, 1975; for Horticultural Research Association). No reprints.

    A review of the physical and chemical characteristics that determine the water, oxygen and nutrient economies of horticultural peat. Introduction of standards should promote quality control and assist growers to select an appropriate type for a particular purpose.

24. Post-glacial change in vegetation. By S. E. Durno. (pp. 20-37 of *Plant communities and soils of the Lowland and Southern Upland regions of Scotland*. Edited by E. L. Birse and J. S. Robertson. *Soil Survey of Scotland Monograph*. Aberdeen: Macaulay Institute for Soil Research, 1976). No reprints.

    An account of change in the post-glacial vegetational history of the Lowland and Southern Upland regions of Scotland is based mainly on the evidence of pollen analysis.

25. Effect of nitrogen supply on nutrients in litter fall and crown leaching. By H. G. Miller, J. M. Cooper and J. D. Miller. (*J. Appl. Ecol.*, **13**, 233-248, 1976).

    The effect of nitrogen fertilizer on the release of nutrients in litter and by crown leaching was studied in pole-stage Corsican pine. Fertilizers increased the

weight of needle fall and the percentages of nitrogen and potassium in needle-litter. Crown leaching accounted for less than half the quantity of some nutrients gained by rainwater on passing through the canopy, the rest being derived from air-borne particles. Crown leaching accounted for most of the sodium and slightly less than half of the magnesium and potassium released by the trees.

26. Effect of nitrogen supply on net primary production in Corsican pine. By H. G. Miller and J. D. Miller. (*J. Appl. Ecol.*, **13**, 249-256, 1976).

Application of nitrogen fertilizer to a crop of Corsican pine increased both the foliage area per area of ground surface and the photosynthetic rate per area of foliage. Foliage area increased initially through improved needle retention and subsequently through a progressive increase in the number and size of needles. Net primary production was unaltered in the first year of treatment but by the third year very high values were achieved.

27. Analysis of needle fall as a means of assessing nitrogen status in pine. By H. G. Miller and J. D. Miller. (*Forestry*, **49**, 57-61, 1976).

Levels of nitrogen in October needle fall are closely related to the levels in fresh foliage and could be used to monitor the development of nitrogen deficiency in Corsican pine.

28. Tree growth and climatic cycles in the rain-shadow of the Grampian mountains. By H. G. Miller and J. M. Cooper. (*Nature, Lond.*, **260**, 697-698, 1976).

Radial growth of mature Scots pine varied on four regular cycles that match oscillations in May rain (23·0 and 11·9 year periods), June rain (4·44 year period) and mean annual temperature (42·0 year period). The cycles in rainfall were limited to the rain-shadow behind the Grampian mountains.

29. Practical developments in atomic fluorescence spectroscopy. By T. S. West. (*Proc. Analyt. Div. Chem. Soc.*, **13**, 266-271, 1976). No reprints.

Some aspects of practical import for the application of atomic fluorescence spectroscopy to trace analysis are reviewed. These include the factors in the equation that relates the analytical signal to the concentration of the trace constituent, and those relating to the choice of the atomic line, atomization technique, and spectral line source. Recent work on the preparation of temperature stabilised electrodeless discharge lamps is discussed and the possibilities of applying non-dispersive atomic fluorescence spectrometry using reflectance optics with time resolution of the analytical signals for binary mixtures of elements.

30. Excitation sources for atomic spectroscopy. By B. L. Sharp. (*Proc. Analyt. Div. Chem. Soc.*, **13**, 40-43, 1976). No reprints.

31. Lasers: their current and potential applications in analytical chemistry. By B. L. Sharp. (*Proc. Analyt. Div. Chem. Soc.*, **13**, 104-107, 1976). No reprints.

32. The determination of rare earths in rocks and soils by spark-source mass spectrometry. By A. M. Ure and J. R. Bacon. (*Proc. Analyt. Div. Chem. Soc.*, **13**, 124-127, 1976).

The determination of the rare earths as a group with an AEI MS702R Spark-Source Mass Spectrometer using photographic recording is described. Sample preparation, interpretation of spectra and standardisation procedures are discussed, together with the problem of interferences and their correction. The method has been used for the analysis of a range of soil and standard rock samples.

33. The role of IR spectroscopy in a soil research institute: I The surface of clays. By V. C. Farmer. (*Europ. Spectrosc. News*, (7), 13-15, 1976). No reprints.

The work of the absorption spectroscopy section at the Macaulay Institute on the surface reactions of soil clays is briefly reviewed in an article of general interest to spectroscopists.

34. Confirmation of the surface structures of goethite (α-FeOOH) and phosphated goethite by infrared spectroscopy. By R. L. Parfitt, J. D. Russell and V. C. Farmer. (*J. Chem. Soc., Faraday Trans.*, **72**, 1082-1087, 1976).

Goethite, an iron oxyhydroxide common in soil, has a strong affinity for phosphate ion. It is shown that the phosphate is adsorbed as acid phosphate groups from both acid and alkaline solutions. A detailed structure of the goethite surface, proposed previously, is shown to account for all the features associated with surface groups that are seen in infrared spectra of goethite, phosphate-treated goethite, and fluoride-treated goethite.

35. A Mössbauer and infrared spectroscopic study of the structure of nontronite. By B. A. Goodman, J. D. Russell, A. R. Fraser and F. W. D. Woodhams (Department of Natural Philosophy, University of Aberdeen). (*Clays Clay Min.*, **24**, 53-59, 1976).

Ferruginous smectites are of widespread occurrence in soils and rocks but have been much less closely investigated than their aluminium analogues. With a view to a better understanding of the structure of these iron-rich silicate phases, nontronites from a variety of sources have been analysed by microprobe and studied by Mössbauer and infrared spectroscopy. The results indicated that iron is more randomly distributed between the one tetrahedral and two octahedral sites in the structure than was previously thought.

36. Infrared spectroscopy in mineral chemistry. By V. C. Farmer. (pp. 357-388 of *Physicochemical Methods of Mineral Analysis*. Edited by A. W. Nicol. London: Plenum Press, 1975). No reprints.

The use of infrared spectroscopy in identifying minerals and characterizing their composition, structure and reactions is reviewed and illustrated.

37. A possible relationship between soil fulvic acid and polymaleic acid. By H. A. Anderson and J. D. Russell. (*Nature, Lond.*, **260**, 597, 1976).

Although soil fulvic acid has been the subject of chemical investigation for over a hundred years, no satisfactory model has been proposed for its composition and properties. It is shown here that polymaleic acid very closely matches the natural material in its infrared spectrum, chemical analysis, hydrolysis products and other properties. Certain aspects of the structure of the synthetic product are known and if, as seems likely, there are analogous features in the soil fulvic acid, the former compound could provide information necessary to an understanding of the complexing of nutrient ions by soil organic matter and of its biological activity. These properties are of considerable agricultural importance.

38. The Mössbauer spectrum of a ferrian muscovite and its implications in the assignment of sites in dioctahedral micas. By B. A. Goodman. (*Mineralog. Mag.*, **40**, 513-517, 1976).

On the basis of new results obtained by Mössbauer spectroscopy, a modified scheme for the assignment of cation sites in dioctohedral micas is proposed.

39. On the interpretation of the Mössbauer spectra of biotites. By B. A. Goodman. (*Am. Miner.*, **61**, 169, 1976).

Criticisms by Bancroft and Brown (*Am. Miner.* **60**, 265-272, 1975) of the interpretation of the Mössbauer spectra of biotite by Goodman and Wilson (*Mineralog. Mag.*, **39**, 448-454, 1973) are answered.

40. The composition of soil humus. By M. V. Cheshire, B. A. Goodman and C. M. Mundie. (pp. 73-90 of *Rep. Welsh Soils Discussion Group*, (16), 1975).

The composition of soil humus is discussed with particular attention to the polysaccharide and humic acid fractions.

41. The bonding of vanadium in complexes with humic acid: an electron paramagnetic resonance study. By B. A. Goodman and M. V. Cheshire. (*Geochim. Cosmochim, Acta.*, **39**, 1711-1713, 1975).

An electron paramagnetic resonance study has been made of the complexes formed by the addition of vanadium salts to the humic acid fraction of a peat. The vanadium in these complexes is in the vanadyl form and is bound to oxygen-containing groups in the humic acid.

42. The occurrence of copper-porphyrin complexes in soil humic acids. By B. A. Goodman and M. V. Cheshire. (*J. Soil Sci.*, **27**, 337-347, 1976).

Humic acids from a range of soils representative of a large area of land of North East Scotland have all been shown by electron paramagnetic resonance studies to contain copper-porphyrin complexes.

43. The effect of temperature on the microbial transformation of [^{14}C] glucose during incubation in soil. By M. V. Cheshire, M. P. Greaves and C. M. Mundie. (*J. Soil Sci.*, **27**, 75-88, 1976).

    Although incubation of soil with glucose at about 20°C produces polysaccharide low in arabinose and xylose compared with natural soil polysaccharide, incubation at winter field temperature results in production of xylose in amounts corresponding to that observed in soil. Yeasts appear to be responsible for xylose synthesis.

44. Automated determination of monosaccharides using *p*-hydroxybenzoic acid hydrazide. By C. M. Mundie, M. V. Cheshire, H. A. Anderson and R. H. E. Inkson. (*Analyt. Biochem.*, **71**, 604-607, 1976).

    A method for analysing resin column chromatographic separates of sugars in a Technicon AutoAnalyzer is described.

45. The identification and determination of glucuronic and galacturonic acids in Scottish soils and soil fractions using ion-exchange and gas-liquid chromatography. By C. M. Mundie. (*J. Soil Sci.*, **27**, 331-336, 1976).

    Uronic acids occur in soils as components of polysaccharides which are thought to play an important role in stabilizing soil aggregates. Two methods have been used for identifying and measuring amounts of individual uronic acids in a number of Scottish soils and soil fractions. The presence of glucuronic and galacturonic acids in soil has been confirmed, galacturonic acid appearing in slightly greater amounts than glucuronic acid. Mannuronic acid was not detected and was subsequently used as an internal standard.

46. Organic sulphur fractions in Scottish soils. By N. M. Scott and G. Anderson. (*J. Sci. Fd. Agric.*, **27**, 358-366, 1976).

    Over 90 per cent of the total sulphur in acid surface soils from north Scotland is in organic combination and the proportion is not influenced by soil parent material. In a group of calcareous soils derived from shell sand, on the other hand, only 11 to 79 per cent of the sulphur is in organic form. On average, 64 per cent of the organic sulphur in the acid soils, and 23 per cent in the calcareous soils, is in the form of sulphate, the remainder being directly bonded to carbon. The organic sulphur forms a very consistent proportion of the organic matter, the N:S ratios falling within the narrow range of 6·0 to 7·5.

47. Sulphur, carbon and nitrogen contents of organic fractions from acetylacetone extracts of soils. By N. M. Scott and G. Anderson. (*J. Soil Sci.*, **27**, 324-330, 1976).

    Ultrasonic dispersion of acid-pretreated soils in aqueous acetylacetone at pH 8 extracted a large proportion of the organic sulphur from five Scottish soils. Subsequent gel permeation chromatography of the extracts yielded fractions containing from 14 to 60 per cent of the soil organic sulphur, which should provide useful starting materials for qualitative investigations on the nature of soil organic sulphur.

48. Some effects of a fulvic acid component of soil organic matter on the growth of cultured tomato roots. By D. J. Linehan. (*Soil. Biol. Biochem.*, **8**, 511-517, 1976).

    A fulvic acid component of soil organic matter, known to be chemically similar to the soluble humus present in soil solution, has been shown to increase the growth rate of cultured isolated tomato roots. Cell expansion is increased as is protein synthesis and the development of lateral root primordia. Evidence is presented indicating that the enhanced growth results from changes in the balance of endogenous growth regulators in the root.

49. The growth of wheat plants in humic acid solutions under axenic conditions. By D. Vaughan and D. J. Linehan. (*Pl. Soil*, **44**, 445-449, 1976).

    The effects of soil organic matter on the growth of higher plants under axenic conditions are described. The general appearance of axenic plants was indistinguishable from that of plants grown in association with microbes. Humic acid enhanced the growth of both the roots and shoots of plants under axenic conditions showing that soil organic matter can affect plant growth in the absence of microbes.

50. Some effects of humic acid on cation uptake by parenchyma tissue. By D. Vaughan and I. R. MacDonald. (*Soil Biol. Biochem.*, **8**, 415-421, 1976).

Soil organic matter can affect plant nutrition in a number of ways, for example, by influencing the uptake into plant tissue of metal ions. Thus humic acid stimulates the uptake of sodium and barium, has no effect on calcium and inhibits the uptake of zinc. The selective effect of humic acid on the uptake of metal ions and on protein synthesis strengthens the view that soil organic matter influences only some aspects of protein metabolism which may play a key role in plant growth.

51. Effects of some chelating and phenolic substances on the growth of excised pea root segments. By P. C. DeKock and D. Vaughan. (*Planta*, **126**, 187-195, 1975).

The growth of pea root segments in a sucrose culture medium is stimulated in the presence of several chelating and phenolic substances. Many of the phenols used can be derived by oxidation or hydrolysis of humic acid, and hence the elucidation of the mechanism by which they stimulate plant growth may lead to a greater understanding of the mode of action of soil organic matter.

52. Gravity counteracts light-induced inhibition of root growth. By I. R. MacDonald. (*Nature, Lond.*, **263**, 584-585, 1976).

Light inhibits the rate of growth of some roots by a mechanism which is not understood but which, it has been suggested, may be related to that which controls the response of the root to gravity. This study shows that the light-induced inhibition of seedling roots is most pronounced on a horizontal plane and it can be overcome by orientating the roots vertically or by subjecting them to a force field.

53. Metabolic changes associated with calcium deficiency in potato sprouts. By P. C. DeKock, P. W. Dyson, A. Hall and F. Grabowska. (*Potato Res.*, **18**, 573-581, 1975).

Sprouts from potato tuber pieces (sets) placed in washed sand soon cease to grow and the tips blacken. Calcium applied to the tip prevents the blackening and allows growth to continue. The changes in the contents of the major elements and citric, malic and chlorogenic acids have been studied.

54. An examination, by compartmental flux analysis, of the development of sodium and chloride absorption capacities in beetroot disks. By A. E. S. Macklon. (*J. Exp. Bot.*, **27**, 651-657, 1976).

When dormant beetroot storage tissue is sliced and placed in aerated solution, metabolic activity is immediately stimulated, but there is a delay of several hours before net ion accumulation occurs. The present work confirms the view that sodium influx is high from the outset, net accumulation awaiting the reduction of an initially high efflux, and that net chloride absorption results from a marked increase in influx. The fluxes at both the cell membrane and the vacuole membrane of the tissue cells have been estimated, and it is shown that the important flux changes leading to net uptake of sodium and chloride both occur at the vacuole membrane.

55. Cortical cell fluxes and transport to the stele in excised root segments of *Allium cepa* L. III. Magnesium. By A. E. S. Macklon and A. Sim. (*Planta*, **128**, 5-9, 1976).

The uptake and loss of magnesium by onion root segments have been examined using a radioactive isotope. In most respects magnesium behaved like calcium. In particular it was found that magnesium, like calcium, entered the cells by passive diffusion down an electro-chemical diffusion gradient, and was maintained at less than equilibrium concentration in the cytoplasm of root cells by an outwardly directed metabolic pump.

56. The effects of storage at chilling temperature on ion absorption, salt retention capacity and respiratory pattern in yam tubers. By A. O. Olorunda and A. E. S. Macklon. (*J. Sci. Fd. Agric.*, **27**, 405-412, 1976).

Cell membrane permeability is a major factor determining the absorption of nutrient ions from the soil solution by plant roots. As one of a number of approaches useful in furthering knowledge of cell membrane function, this paper reports work with yam tuber tissue which is subject to chilling injury at temperatures as high as 10°C, and in which changes of membrane permeability with temperature are unusually marked. The effects of these changes on ion absorption are described.

57. Energy supply and light-enhanced chloride uptake in wheat laminae. By I. R. MacDonald, A. E. S. Macklon and R. W. G. MacLeod. (*Pl. Physiol.*, **56**, 699-702, 1975).

Plants absorb nutrient ions and transport them in the plant using respiratory energy. Leaf cells have an alternative source of energy for this function from photosynthetic reactions. This investigation was designed to assess the relative contributions of these energy sources to ion transport in wheat leaf.

58. The effect of water suctions on the growth of the ciliate *Colpoda steini* and the bacterium *Azotobacter chroococcum* in soil. By J. F. Darbyshire. (*J. Soil Sci.*, **27**, 369-376, 1976).

The size range of soil pores, which must contain moisture as a prerequisite for protozoan growth in soil, is unknown. This paper describes the results of experiments with the soil protozoan, *Colpoda steini*, and the soil bacterium, *Azotobacter chroococcum*, inoculated into sterile soil samples with the pores in specific size ranges subsequently drained by suction. The duration of protozoan growth increased as the degree of suction applied was reduced and the largest protozoan populations occurred in saturated soils.

59. The aerobic bacterial flora of a raised bog. By R. E. Wheatley, M. P. Greaves and R. H. E. Inkson. (*Soil Biol. Biochem.*, **8**, 453-460, 1976).

Microbiological examination of a Aberdeenshire raised bog profile showed that aerobic bacteria were present down to 3 m and that their numbers tended to decrease with depth. The dominant bacteria were spore-formers and the proportion present as spores increased with depth; below 2·5 m no vegetative forms were present. Metabolic determinations suggested that the microbial population was inactive in an undisturbed raised bog.

60. Copper deficiency in plants and effects of copper dressings on crops and herbage. By J. W. S. Reith. (pp. 25-37 of *Proc. Symp. Copper in Farming, London, 1975.* Potters Bar, Herts.: Copper Development Association, 1976). No reprints.

The occurrence and effects of copper deficiency are reviewed. Results from experiments on soils deficient in copper in north-east Scotland show that applied copper increased the yield of grain but had little or no effect on the yields of straw, potatoes, swedish turnips or herbage. All the crops had low copper contents which were normally increased by applying this nutrient. Without applied copper, the mean copper content in herbage gradually fell when 200 kg/ha nitrogen was applied annually for three years. Where copper was applied this nitrogen treatment increased the content compared with no nitrogen. On these soils copper dressings have continued to be effective for ten to eighteen years after application.

61. Sulphate contents and sorption in Scottish soils. By N. M. Scott. (*J. Sci. Fd. Agric.*, **27**, 367-372, 1976).

Agricultural surface soils from contrasting soil series in north-east Scotland contain considerable reserves of available inorganic sulphate, mostly in the adsorbed form, and there are no known cases of sulphur deficiency in the area. In most instances, retention of added sulphate, unlike phosphate, depends more on active iron than aluminium. The abilities of the different soils to retain sulphate, and hence the content of adsorbed sulphate, therefore vary markedly depending on the nature of the soil parent material, but are not greatly affected by the pedological drainage status.

62. Characterization of mobile aluminium in acid soils. By B. W. Bache and G. S. Sharp. (*Geoderma*, **15**, 91-101, 1976).

Crop growth on acid soils is often inhibited by aluminium toxicity, and it is therefore necessary to be able to characterize soils with regard to their aluminium status. Because soluble aluminium is a component of the calcium-aluminium cation-exchange system, a ratio of the concentrations of calcium to aluminium in soil solution is proposed as the most appropriate way of doing this. Leaching soils slowly with concentrated potassium chloride solution released total mobile aluminium; this consisted of exchangeable aluminium, displaced in the early stages and non-exchangeable aluminium released later. It proved impossible to differentiate clearly between these two fractions, but approximate values were obtained.

63. Soluble polymeric hydroxy aluminium ions in acid soils. By B. W. Bache and G. S. Sharp. (*J. Soil Sci.*, **27**, 164-174, 1976).

An important feature of acid soils, from the point of view of crop growth is the presence of aluminium ions in the soil solution and as part of the cation exchange complex. While much soluble aluminium occurs as the simple trivalent ion $[Al(H_2O)_6]^{3+}$, this report shows that considerable amounts of soluble and exchangeable aluminium are present as polynuclear hydroxy aluminium ions. As pH rises from 3·6 to 5·2, the total amount of soluble and exchangeable Al drops to almost zero, but the proportion in polynuclear form rises to 80 per cent.

64. The measurement of cation exchange capacity of soils. By B. W. Bache. (*J. Sci. Fd. Agric.*, **27**, 273-280, 1976).

Cation exchange capacity, CEC, is an important property extensively used for characterizing soils for survey purposes and for assessing their ability to supply cation nutrients to crops. This paper examines the implications of the different methods available for measuring CEC in the light of current knowledge, and discusses the issues involved in selecting suitable methods for particular purposes.

65. The bioclimate of Scotland in relation to a world system of classification and to land use capability. By E. L. Birse. (*Trans. Bot. Soc. Edin.*, **42**, 463-467, 1976).

The bioclimate of Scotland has been characterized by oceanicity, moisture balance and thermal zonation. These form six regions which are placed within the framework of a possible world system. For land use capability a finer division is necessary and the addition of corrections for latitude and oceanicity to the scheme now in use is proposed.

66. Plant communities and soils of the Lowland and Southern Upland regions of Scotland. By E. L. Birse and J. S. Robertson. (*Monogr. Soil Surv. Scotl.* 226 pp. Aberdeen: Macaulay Institute for Soil Research, 1976).

The natural and semi-natural vegetation of Lowland and Southern Upland Scotland is described, plant communities named and detailed species tables given. The classification used is similar to that used on the European mainland. A chapter links soil types with their associated vegetation. Background information is given on climate, geology, the parent materials of soils and the changes in vegetation after the last Ice Age. Distribution maps of the more widespread plant communities are included.

67. Natural and seminatural vegetation of the Nairn and Cawdor district. By E. L. Birse and J. S. Robertson. (*Bull. Soil Surv. Scotl. no. 3*. 108 pp. with vegetation map. Aberdeen: Macaulay Institute for Soil Research, 1976).

A map of the natural and seminatural vegetation of 173 square kilometres of Nairnshire has been drawn on a scale of 1:25 000. The bulletin accompanying the map gives a short description of the basic mapping units and indicates their relationship with soils and climate.

68. Attachment for lapping consolidated materials with particular reference to the preparation of soil thin sections. By L. Robertson and J. H. Normington. (*Lab. Practice*, **25**, 470-471, 1976).

A sample holder, to be used in conjunction with a rotating lapping machine for the preparation of flat polished surfaces of consolidated materials, is described. Although primarily designed for use in connection with the production of soil thin sections for micromorphological studies, it is equally suited to the preparation of petrographic and metallurgical specimens.

69. Some genetic characteristics of the freely drained soils of the Ettrick Association in east Scotland. By J. C. C. Romans and L. Robertson. (*Geoderma*, **14**, 297-317, 1975).

This paper describes the interrelated characteristics of the freely drained soil series of the Ettrick Association. These soils are extensively developed in the Southern Uplands of Scotland on glacial drift derived from greywacke.

At the present day the soils of the Linhope series are acid brown soils whereas the Minchmoor and Dod series include podzols and peaty podzols. Sub-alpine podzols and alpine soils are included within the Merrick series. It is concluded that the soils of the Linhope, Minchmoor and Dod series were all formerly

brown forest soils under deciduous woodland. They have evolved to their present status after forest clearance which gathered momentum after the widespread establishment of monastic institutions in Scotland in the 12th and 13th centuries A.D. The evolutionary outline of profile development is described and discussed.

70. Design and production of 1:25 000 single-colour soil maps. By W. S. Shirreffs. (*Cartograph. J.*, June 1976, pp. 55-59). No reprints.

An account is given of the factors involved in the design of 1:25 000 scale single-colour soil maps together with a description of the procedures involved in their production.

71. The soils of the country round Perth, Arbroath and Dundee. By D. Laing. (*Mem. Soil Surv. Gt. Br.* Edinburgh: H.M.S.O., 1976).

The 57 soil series mapped in the area (1375 km², 550 square miles) are described and classified. Chemical data are quoted for 110 soil profiles and further chemical, spectrochemical and mineralogical analyses are given for selected soils. Ancillary chapters give information on physiography, climate, geology and soil parent materials, agriculture and forestry and plant communities are described in relation to soils. An assessment is made of the land use capability of the area in terms of the limitations imposed by soils and the natural factors of site and climate.

The memoir includes coloured soil and land use capability maps on the scale of 1 inch to 1 mile.

72. Indurated layers. J. C. C. Romans. (pp. 20-30 of *Proc. N. Engl. Soils Discuss. Gp.*, **11**, 1976). No reprints.
The origin of indurated layers is discussed, with particular reference to the north-east and east of Scotland. An attempt is made to distinguish compact layers in the solum, which owe their origin to the translocation of fine material under periglacial conditions, from the cemented B horizons in podzolic soils which have developed since the climate became warmer.

(B) *Awaiting publication at 30th September, 1976*

73. Crystal structure of aluminium iodate—hydrogen iodate—water (1/1/6) and preparation of anhydrous aluminium iodate. By P. D. Cradwick and (the late) A. S. de Endredy. (*J. Chem. Soc., Dalton Trans.*, (2), 146-149, 1977).

74. Pyrolysis studies on humus in freely drained Scottish soils. By J. M. Bracewell and G. W. Robertson. (To appear in *Proc. 3rd Int. Symp. Analytical Pyrolysis, Amsterdam 1976*).

75. Complementary techniques. By R. C. Mackenzie. (To appear in *Thermogravimetry*. Edited by J. P. Redfern and C. J. Keattch. London: Butterworths).

76. Electron probe microanalysis of cell walls of *Cunninghamella echinulata*. By D. Jones, W. J. McHardy, V. C. Farmer and Y. Jones (Department of Biological Sciences, University of Dundee). (Submitted to *Trans. Br. Mycol. Soc.*).

77. Halloysite in some soils from north-east Scotland. By M. J. Wilson and J. M. Tait. (Submitted to *Clay Minerals*).

78. The pedogenisis of some gibbsitic soils from the Southern Uplands of Scotland. By M. J. Wilson and C. J. Brown. (*J. Soil Sci.*, **27**, 513-522, 1976).

79. Calculated X-ray diffraction curves for the interpretation of a three component interstratified system. By P. D. Cradwick and M. J. Wilson. (Submitted to *Clay Minerals*).

80. General theory for the one-dimensional scattering of X-rays from interstratified clay minerals. By P. D. Cradwick. (Submitted to *Clay Minerals*).

81. Structure of the crown ether complex: $Ca(benzo\text{-}15\text{-}crown\text{-}5)_2$ (3, 5-dinitrobenzoate)$_2$, $3H_2O$. By P. D. Cradwick and N. S. Poonia (Vikram University, India). (*Acta Cystallogr.*, **B33**, 197-199, 1977).

82. The weathering of chlorite in some Scottish soils. By D. C. Bain. (Submitted to *J. Soil Sci.*).

83. The weathering of ferruginous chlorite in a podzol from Argyllshire, Scotland. By D. C. Bain. (Submitted to *Geoderma*).

84. Specific surface area and pore structure of allophanic soil clays. By E. Paterson. (Submitted to *Clay Minerals*).

85. A graphical method of comparing regional vegetation succession in Scotland. By S. E. Durno. (Submitted to *Trans. Proc. Bot. Soc., Edin.*).

86. A simple device for recording maximum and minimum water-table levels in soils. By R. Boggie. (Submitted to *J. Appl. Ecol.*).

87. Water-table depth and oxygen content of deep peat in relation to root growth of *Pinus contorta*. By R. Boggie. (Submitted to *Pl. Soil*).

88. Tracing water movement, using tritium, in a peaty gley soil under Sitka spruce. By R. Boggie and A. H. Knight. (Submitted to *Forestry*).

89. Apparatus for collecting rainwater and litter fall beneath forest vegetation. By J. D. Miller and H. G. Miller. (*Lab. Practice*, **25**, 850-851, 1976).

90. Effect of nitrogen supply on nutrient uptake in Corsican pine. By H. G. Miller, J. D. Miller and O. J. L. Pauline. (*J. Appl. Ecol.*, **13**, 955-966, 1976).

91. Growth of Scots pine under nutritional and climatic stress By H. G. Miller, J. D. Miller and W. O. Binns. (Submitted to *Pl. Soil*).

92. Growth of *Pinus contorta* at different water-table levels in deep blanket peat. By R. Boggie and H. G. Miller. (*Forestry*, **49**, 123-131, 1976).

93. The characterization by Mössbauer spectroscopy of the secondary iron in pans formed in Scottish podzolic soils. By B. A. Goodman and M. L. Berrow. (*J. Phys., Paris*, **37**, Colloque C6, 849-855, 1976).

94. The determination of cadmium in plant material and soil extracts by solvent extraction and atomic absorption with a carbon-rod atomizer. By A. M. Ure and M. C. Mitchell. (*Analytica Chim. Acta*, **87**, 283-290, 1976).

95. Dissolution of mercury (II) sulphide by digestion with sulphuric acid-nitric acid and oxidation with potassium permanganate. By A. M. Ure. (*Analyst*, **102**, 50-51, 1977).

96. Quantitative determination of minor and trace elements in rocks and soils by spark-source mass spectrometry. By A. M. Ure and J. R. Bacon. (To appear in *Proc. 7th Int. Mass Spectrometry Conf., Florence 1976*).

97. Adsorption on hydrous oxides: I Oxalate and benzoate on goethite. By R. L. Parfitt, V. C. Farmer and J. D. Russell. (Submitted to *J. Soil Sci.*).

98. Adsorption on hydrous oxides: IV Mechanisms of adsorption of various ions on goethite. By R. L. Parfitt and J. D. Russell. (Submitted to *J. Soil Sci.*).

99. Adsorption on hydrous oxides: III Fulvic acid and humic acid on goethite, gibbsite and imogolite. By R. L. Parfitt, A. R. Fraser and V. C. Farmer. (Submitted to *J. Soil Sci.*).

100. Adsorption on hydrous oxides: II Oxalate, benzoate and phosphate on gibbsite. By R. L. Parfitt, A. R. Fraser, J. D. Russell and V. C. Farmer. (Submitted to *J. Soil Sci.*).

101. Recognition of imogolite structures in allophanic clays by infrared spectroscopy. By V. C. Farmer, A. R. Fraser, J. D. Russell and N. Yoshinaga (Ehime University, Japan). (Submitted to *Clay Minerals*).

102. Comment on "Contamination of humic acid by silica gel and sodium bicarbonate" by K. H. Tan. By J. D. Russell and H. A. Anderson. (Submitted to *Pl. Soil*).

103. The effect of lattice substitutions on the derivation of quantitative site populations from the Mössbauer spectra of 2:1 layer lattice silicates. By B. A. Goodman. (*J. Phys., Paris*, **37**, Colloque C6, 819-823, 1976).

104 Assessing organic phosphorus in soils. By G. Anderson. (To appear in *Proc. Symp. Role of Phosphorus in Agriculture, Alabama, 1976*).

105. Polysaccharides in soils. By M. V. Cheshire. (To appear in *Encyclopedia of Earth Sciences: Volume VI B Soil Science*).

106. Origins and stability of soil polysaccharide. By M. V. Cheshire. (Submitted to *J. Soil Sci.*).

107. A comparison of the polycarboxylic acids extracted by water from an agricultural top soil with those extracted by alkali. By D. J. Linehan. (Submitted to *J. Soil Sci.*).

108. A comparison of the growth promoting properties of soil fulvic acid with those of a synthetic polycarboxylic acid. By D. J. Linehan. (Submitted to *Soil Biol. Biochem.*).

109. A disposable petri dish modified for plant growth. By D. C. Gordon and I. R. Macdonald. (*Ann. Appl. Biol.*, **85**, 317-318, 1977).

110. A study of peroxidase and catalase in the the potato tuber. By P. C. DeKock, A. Hall and R. H. E. Inkson. (Submitted to *Ann. Bot.*).

111. Nutrient distribution in the potato tuber in relation to soil pH. By P. C. DeKock, A. Hall and R. H. E. Inkson. (Submitted to *Ann. Bot.*).

112. Some microbial and chemical changes in soil near the roots of spring barley, *Hordeum vulgare* L., infected with take-all disease. By J. F. Darbyshire, M. S. Davidson, N. M. Scott and P. J. Shipton (North of Scotland College of Agriculture). To appear in *Proc. 6th Int. Colloq. Soil Zoology, Uppsala, Sweden 1976*).

113. Infection of plant tissue by *Sclerotinia sclerotiorum*: a scanning electron microscope study. By D. Jones. (*Micron*, **7**, 275-279, 1976).

114. *Paratetramitus jugosus*, an amoeba-flagellate of soils and freshwater, type-species of *Paratetramitus* nov. gen. By J. F. Darbyshire, F. C. Page (N.E.R.C. Culture Centre for Protozoa and Algae, Cambridge) and L. P. Goodfellow (N.E.R.C. Culture Centre for Protozoa and Algae, Cambridge). (*Protistologica*, **12**, 375-387, 1976).

115. The morphology of a common soil flagellate, *Heteromita globosa* Stein (Mastigophorea: Protozoa). By C. M. Macdonald, J. F. Darbyshire and C. G. Ogden (British Museum (Natural History), London). (Submitted to *Bull. Br. Mus. (Nat. Hist.): Zoology*).

116. Nitrogen fixation by *Azotobacter chroococcum* in the presence of *Colpoda steini*: III Dissolved oxygen tension in large batch cultures. By J. F. Darbyshire and M. S. Davidson. (Submitted to *Soil Biol. Biochem.*).

117. An investigation into the relations between some growth parameters and yield of barley. By P. W. Dyson. (Submitted to *Ann. Appl. Biol.*).

118. Relationships between grain yield and the nitrogen and excess base contents of young barley plants. By W. M. Crooke. (Submitted to *J. Sci. Fd. Agric.*).

119. Soil reaction. By B. W. Bache. (To appear in *Encyclopedia of Earth Sciences: Volume VI B Soil Science*).

120. Base saturation. By B. W. Bache. (To appear in *Encyclopedia of Earth Sciences: Volume VI B Soil Science*).

121. Activity ratio. By B. W. Bache. (To appear in *Encyclopedia of Earth Sciences: Volume VI B Soil Science*).

122. Chemical composition of soils. By B. W. Bache. (To appear in *Encyclopedia of Earth Sciences: Volume VI B Soil Science*).

123. Soil solution. By B. W. Bache. (To appear in *Encyclopedia of Earth Sciences: Volume VI B Soil Science*).

124. The development of a solid state reference electrode for use in soil measurements. By G. P. Bound and B. Fleet (Imperial College of Science and Technology, London). (Submitted to *J. Sci. Fd. Agric.*).

125. Determination of nitrate in soil pastes by ion selective electrodes. By G. P. Bound. (Submitted to *J. Sci. Fd Agric.*).

126. Long term culture methods for the production of isotopically labelled plant material. By A. H. Knight. (Submitted to *New Phytol.*).

127. Tracing magnesium. By A. H. Knight and H. Shepherd. (*Newsl. Applic. Nucl. Meth. Biol. Agric.*, (7), 13-14, 1976).

128. Anthyllido-Rhacomitrietum canescentis ass. nov. prov. dans la region Grampian de l'Ecosse. By E. L. Birse. (*Doc Phytosociol.*, NS **1**, 19-22, 1977).

129. Three soil profiles from Elephant Island. By R. M. G. O'Brien, (Grampian Region, Elgin Office), J. C. C. Romans and L. Robertson. (Submitted to *Br. Antarct. Surv. Bull.*).

130. Soils. By B. M. Shipley. (Submitted to *Soils Section of "Report on the Slamannan Drainage Project" for the West of Scotland Agricultural College*).

131. The recording and organisation of soil survey field data for computer areal mapping. By J. M. Ragg. (Submitted to *Geoderma*).

132. Soils of the area around the Burn, Edzell. By J. C. C. Romans. (To appear in *The Burn Guide*. Dominion Students Hall Trust).

AGRICULTURAL RESEARCH INSTITUTES IN GREAT BRITAIN

The research programmes of the following agricultural research institutes supported by public funds are co-ordinated by the Agricultural Research Council. These institutes generally publish annual reports or periodical reports summarizing the research work that is in progress. Full details can be obtained from the secretaries of the institutes concerned.

A.R.C. Institutes

Animal Breeding Research Organization	King's Buildings, West Mains Road, Edinburgh, EH9 3JQ.
Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT.
Institute for Research on Animal Diseases	Compton, Newbury, Berks, RG16 0NN.
Food Research Institute	Colney Lane, Norwich, NR4 7UA.
Meat Research Institute	Langford, Bristol, BS18 7DY.
Poultry Research Centre	King's Buildings, West Mains Road, Edinburgh, EH9 3JS.
Letcombe Laboratory	Letcombe Regis, Wantage, Oxfordshire, OX12 9JT.
Weed Research Organization	Begbroke Hill, Sandy Lane, Yarnton, Oxford, OX5 1PF.

State-aided Institutes (Scotland)

Animal Diseases Research Association	Moredun Institute, 408 Gilmerton Road, Edinburgh, EH17 7JH.
Hannah Research Institute	Ayr, KH6 5HL.
Hill Farming Research Organization	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Institute for Agricultural Engineering	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Scottish Horticultural Research Institute	Invergowrie, Dundee, DD2 5DA.
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian, EH25 9RF.

State-aided Institutes (England and Wales)

Animal Virus Research Institute	Pirbright, Woking, Surrey, GU24 0NF.
East Malling Research Station	East Malling, Maidstone, Kent, ME19 6BJ
Glasshouse Crops Research Institute	Worthing Road, Rustington, Littlehampton, Sussex, BN16 3PU.
Grassland Research Institute	Hurley, Maidenhead, Berks, SL6 5LR.
Houghton Poultry Research Station	Houghton, Huntingdon, PE17 2DA.
John Innes Institute	Colney Lane, Norwich, NOR 7OF.
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF.
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Beds, MK45 4HS.
National Institute for Research in Dairying	Shinfield, Reading, Berks, RG2 9AT.
National Vegetable Research Station	Wellesbourne, Warwick, CV35 9EF.
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ.
Rothamsted Experimental Station	Harpenden, Herts., AL5 2JQ.
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth Cardiganshire, SY23 3EB.
Wye College, Department of Hop Research	Ashford, Kent, TN25 5AH.